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A PRELIMINARY EVALUATION OF

THE PIT INCINERATOR

A Division of Technical Operations
Open-File Report (TO 3.1.008/0)

written by
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U.S. ENVIRONMENTAL PROTECTION AGENCY
Solid Waste Management Office
1971

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BACKGROUND

Incineration is an important method of solid waste processing in the United States, and although over 300 municipal incinerators are in operation, little information on the performance of these units is available. It is, therefore, not surprising that the effects of incineration on the environment are little understood and frequently ignored.

An incinerator discharges effluents into the environment in three states: solid, liquid, and gaseous. The sources of these effluents are the processes of combustion, gas cleaning, and residue quenching. Any determination of the pollution contribution to the environment by incineration must be concerned with all these effluents.

The Solid Waste Management Office of the U.S. Environmental Protection Agency, through the Division of Technical Operations, has initiated a program to characterize the performance of incinerators of different designs and configurations. The primary objectives of this program are to produce basic information that identifies the results of the incineration process and to develop reliable sampling methodology.

During the studies it is considered necessary to make a complete analysis of all features that affect the operation of the facility as well as those that influence its potential for environmental pollution. The operation of the facility during the study is not altered in any way unless specific study objectives dictate a change. Therefore, no special effort is made to operate the facility at its design capacity; rather, it is tested at its "operating" capacity.

Reports from each study in this program will be prepared primarily for use by the management of the facility. Each report will contain only the data obtained during one individual study. Data comparisons with other studies will not be made in individual study reports. Summaries and comparisons of the data from all studies will be reported annually.

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SUMMARY

The pit incinerator is essentially a refractory-lined box with an open top which is screened to catch large particles of fly ash. The interior dimensions of the box are approximately 16 ft by 9 ft by 10 ft high. Solid waste is charged through a door in the screen and burned in a pile on the floor of the box. The unit is designed to be continually operated for a maximum of 8 to 12 hr. The unit is batch charged every 4 to 10 min. After charging is stopped the waste is allowed to burn down and cool whereupon the residue is removed and the operation cycle repeated. Combustion air is supplied by a forced draft fan through a series of nozzles located at the top of the box. Later designs have another series of air nozzles located at the bottom of the box (the test unit had both underfire and overfire air nozzles). The combustion air is so directed as to induce a rolling action within the box. In addition to obtaining good mixing of gases in the box, this rolling action is designed to prevent particles of fly ash from escaping the unit until completely burned.

The primary objective of this preliminary evaluation was to determine reliable techniques for sampling and evaluating a pit incinerator. Because of the problems experienced in obtaining the air pollution data (see Discussion), extreme caution should be exercised in any interpretation or usage of these data. The other data gathered during this study are valid.

Operating Characteristics and Air Pollution Emissions

The test unit was designed to incinerate high calorific value waste, in this case nylon. The designers, Thermal Research and

Engineering Corporation*, anticipated operating difficulties when using this particular unit to incinerate municipal solid waste (see Appendix A). Because of the difficulty and time required to modify the test unit, it was decided to conduct the tests without changing the unit. Operating problems were considerable The flame characteristics were not as they should have been. From the visible emission data and personal observations by the test team, fly ash emissions to the atmosphere were excessive; and in fact, fly ash was deposited over the surrounding area. The unit, if operated in this manner, would create a nuisance. After the first day of testing, it was decided that the unit must be modified to handle low calorific waste if a true evaluation of the pit incinerator was to be obtained.

The unit was modified by changing the angle of the overfire air nozzles. The flame characteristics were improved the second day of testing and the nuisance from the fly ash emissions greatly reduced. The data on particulate emissions are probably not valid because of the sampling problems encountered during the study (see Discussion).

On both days of testing, the unit produced a residue containing very little combustible material. Due to the high combustion temperatures on the second day, most of the residue was in the form of slag. This slag was difficult to remove from the incinerator and required considerable hand labor.

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*Mention of commercial products or companies does not imply endorsement by the U.S. Government.

The unit incinerated municipal solid waste efficiently. The consumption of combustible material was essentially complete during both days of operation. However, the burning rate was 75 percent greater for the second day of operation (3.5 tons per hr, 140 percent of design, as compared to 2.0 tons per hr, 80 percent of design).

Solid Waste

Based on wet weights, the major portions of the solid waste charged during the study were paper (54.2 percent), food waste (11.0 percent), metal (12.4 percent), and glass (11.8 percent). The combustible content was 73.9 percent and the noncombustible content was 26.1 percent. The density ranged from 110 to 160 lb per cu yd. During the first day, the waste had an average moisture content of 30.1 percent, a volatile content of 55.6 percent (dry basis), an ash content of 44.4 percent (dry basis), and a heat content of 3,440 Btu per lb (as received). During the second day, the waste averaged 24.4 percent moisture, 64.2 percent volatiles (dry basis), 35.8 percent ash (dry basis), and 4,170 Btu per lb (as received).

Residue

The residue from the first day of operation had a density of 1190 lb per cu yd and was composed of 33.3 percent fines, 1.5 percent unburned combustibles, 15.0 percent metals, and 50.2 percent glass. The residue from the second day of operation was composed of 87 percent slag and 13 percent loose material. The loose material contained 31.6

percent fines, a trace of unburned combustibles, 15.3 percent metal, and 53.1 percent glass. The average density of this loose material was 1090 lb per cu yd and the density of the slag was 4,370 lb per cu yd.

Residue from the first day of operation had a moisture content of 0.8 percent, a volatile content of 0.8 percent (dry basis), an ash content of 99.2 percent (dry basis), and a heat content of 70 Btu per lb (dry basis). The loose material from the second day of operation contained no moisture or volatiles and had a heat content of 60 Btu per lb. The slag portion of the residue was not analyzed.

Plant Efficiency

Based only on the quantities of solid waste and residue, the efficiency of the pit incinerator in terms of volatile reduction, volume reduction, and heat released was 99 percent or greater for both days of operation.

INTRODUCTION

Because of the widespread public interest in the pit incinerator and the lack of quantitative data, the Solid Waste Management Office (SWMO) became interested in testing one of these units. Because of the dissimilarity of this type of unit with the more conventional enclosed incinerators, many difficulties were anticipated in sampling and evaluating a pit incinerator. It was, therefore, decided to conduct the comprehensive evaluation of the pit incinerators in two phases: a preliminary evaluation and an extensive evaluation. The preliminary evaluation (covered by this report) was to identify the problems that would be encountered in sampling and evaluating a pit incinerator. The extensive evaluation was to gather the data on efficiency and pollution potential while incinerating different types of solid waste.

Thermal Research and Engineering Corporation of Conshohocken, Pennsylvania informed the SWMO that a pit incinerator owned and operated by a Monsanto plant located in Greenwood, South Carolina might be available for testing. The SWMO asked the South Carolina State Board of Health to make the initial contact with Monsanto. A meeting was held on April 14, 1970 with these parties attending. At that time, Monsanto was kind enough to give the SWMO permission to test their unit while burning municipal solid waste. These preliminary tests were conducted on May 7 and 8, 1970.

FACILITY DESCRIPTION AND OPERATION

The description of the incinerator that follows was obtained from Bulletin No. 138[1], published by Thermal Research and Engineering Corporation.

The incinerator (Figure 1) is a Model 16-H having a design capacity of 2,700 lb per hr of waste with a high heating value, such as nylon. When burning municipal waste containing a low heating value, the design capacity is 5,000 lb per hr. The design allows the unit to be continuously charged for a maximum of 8-12 hr. The incinerator has a length of 17-1/3 ft, height of 10-1/2 ft, and a width of 10-1/3 ft. The 9-1/2 in. thick walls are made of hollow refractory block which are filled with castable refractory. The castable refractory is also used for the floor. The refractory allows a maximum operating temperature of 2750 F.

A 60 hp motor operates the forced draft fan rated at approximately 17,700 cfm at 13.6 in. w.c. The fan supplies both overfire and underfire air. Manifolds containing nozzles are used to distribute the air. The 3 ft diameter overfire air manifold contains 32 nozzles spaced on 6 in. centers. The inside diameters of the nozzles alternate between 2 and 3 in. There are 16-2 in. inside diameter underfire air nozzles set in the step on the floor of the unit. A manually operated damper must be opened before air flows to the lower nozzles.

Two-4 ft by 6 ft clean-out doors are located on opposite sides of the incinerator. This allows a front-end loader with an extended blade to remove residue from the incinerator. To retain blowing fly ash, a stainless steel wire (1/4 in. mesh) cage encloses the top of the incinerator.

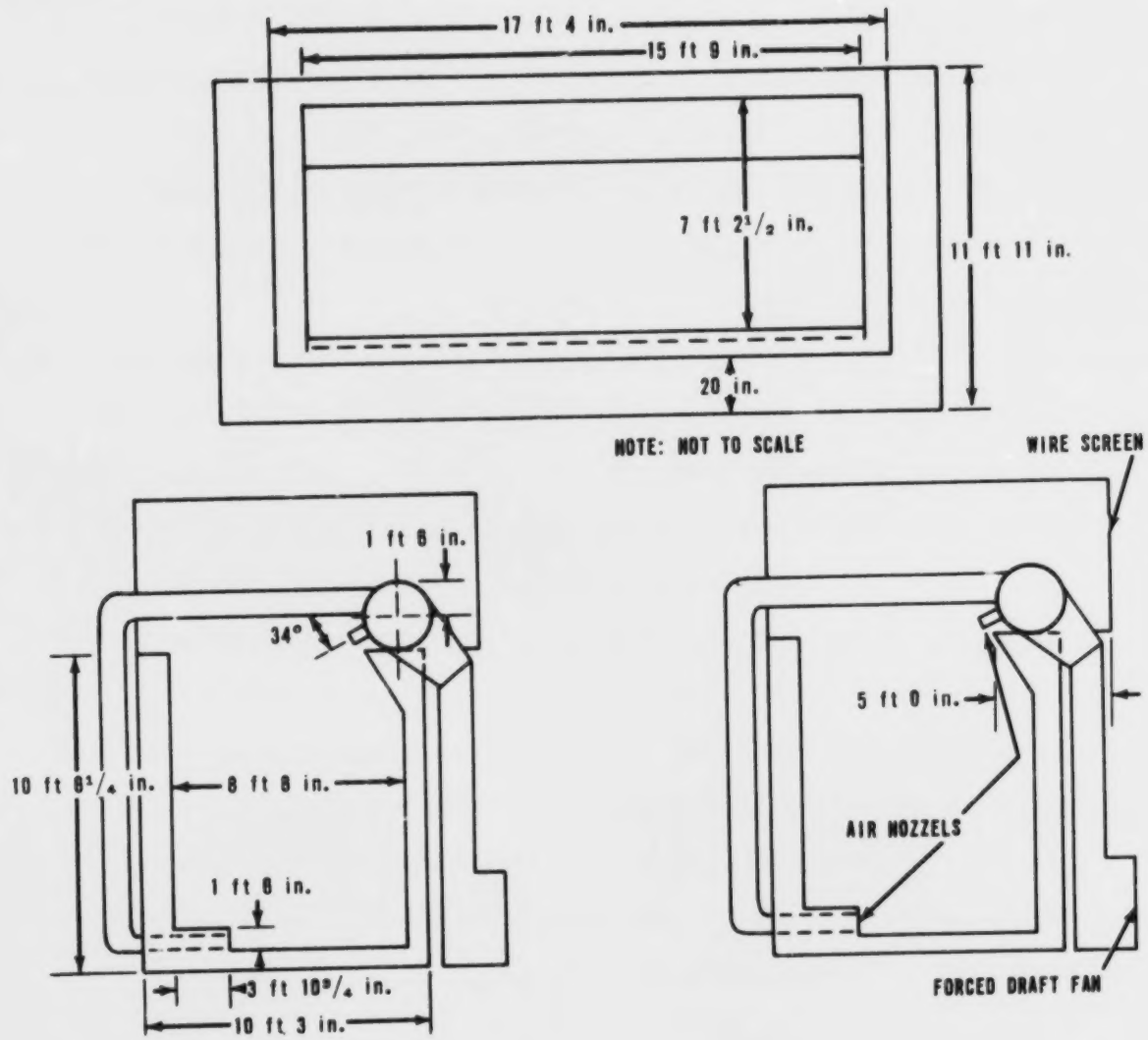

Figure 1. Schematic of pit incinerator.

Solid waste obtained from the City of Greenwood, South Carolina was charged to the incinerator during the study period. Representatives from the incinerator manufacturer, Thermal Research and Engineering Corporation, Conshohocken, Pennsylvania, and Trecan Ltd., Cooksville, Ontario, supervised the operation of the unit.

After light-off, the charging rate was varied until "optimum" combustion was achieved (see Discussion). This condition was achieved before any particulate tests were conducted.

The charging method involved three steps: the forced draft fan was turned off, a load of waste was placed in the pit with a front-end loader, and the fan was turned back on.

Because this unit was designed to burn waste nylon, the air manifold nozzles were angled downward at about 34°. This position was not changed for the perliminary operation and particulate test number one. After the first day of operation this angle was changed to 27°.

After each day of testing, the fan was left operating until the next morning when the residue was sampled and removed from the pit. After the second day of tests a large accumulation of slag was found in the bottom of the unit. Jack-hammers and about 20 man hr of labor were required to remove the slag.

STUDY PROCEDURES

This section discusses the methods used to collect and analyze the following samples: (1) solid waste, (2) residue, (3) particulate emissions, and (4) combustion gases.

Solid Waste

During the study, the charging rates were determined from the weight of solid waste and the time required to burn it.

A total of three samples, visually representative of the waste being burned, were obtained from the storage area. The bulk density of the waste was obtained by placing the entire sample into 20-gal containers and obtaining their net weight. No effort was made to compact the wastes during placement in the containers.

These samples were then spread on a sheet and hand-sorted into nine categories:

Combustibles	Noncombustibles
Food waste	Metal products
Paper products	Glass and ceramics
Plastic, rubber and leather	Ash, rocks, and dirt
Wood	
Garden waste	
Textiles	

Each category was weighed and the percent by weight on an "as received" basis was determined. Using these percentages, 10 to 15 lb laboratory samples were reconstituted from each category keeping the combustible and noncombustible portions separate. To prevent

moisture loss, each of these samples was placed in two plastic bags, one inside the other, and each bag knotted separately.

At the laboratory, the reconstituted samples were dried at 100 to 105 C to constant weight to determine the moisture content. The combustible portions were then processed in a hammermill to reduce the maximum particle size to 1 in. The ground product was spread on a plastic sheet and thoroughly mixed. The sample was then successively mixed and quartered discarding alternate quarters. This process was repeated until a sample weight of 3 to 4 lb was obtained.

A 100-gram portion of the ground sample was redried. The sample was then further ground in a Wiley mill until it would pass through a 2-mm mesh sieve. The volatile* and ash fractions[2] and the heat content[3] were then determined. Ultimate analyses[4] for carbon, hydrogen, oxygen, nitrogen, sulfur, and chlorine were performed on the ground sample. The ash content of the sample submitted for ultimate analyses was also determined.

Residue

The total weight of the residue was also determined. Samples were collected from the incinerator. The bulk density of the residue was obtained by filling a 20-gal container and obtaining the net weight. No effort was made to compact the residue during placement in the container.

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*Material determined by laboratory analysis.

The samples were then spread on a sheet and manually separated into four categories: metals; glass, ceramics, rocks, bricks, etc; unburned combustibles[+]; and fines (material passing a 1/2 in. wire mesh screen). After separation, each category was weighed and the percent by weight on a wet basis was determined. Each category was individually sealed in plastic bags to preserve the moisture content and were returned to the laboratory for further analyses.

At the laboratory, all portions were dried and the fines and unburned combustibles were processed in the same fashion as the solid waste samples, with the following exceptions: the fines were further ground to 60 mesh on an Iler pulverizer and benzoic acid was used as a combustion aid in the calorimeter to determine the heat content. Ultimate analyses were also performed on the ground samples.

The residue sample from the second day of operation did contain small chunks of agglomerated residue, but it did not contain any slag. The slag was not subjected to laboratory analyses; but its density was determined by measuring the volume and weight of a piece of it. The weight of the total quantity of slag was determined by estimating the volume of the slag and calculating the weight using the measured density.

Air Pollution Measurements

Particulate Emissions. On Thursday, May 7, 1970, preliminary measurements were made to determine the moisture content, carbon dioxide content, and velocity of the effluent gases. One particulate emission

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[+]Material that can be visually identified as being from one to six categories of combustible materials used to define the composition of incoming waste, such as charred paper, wood, orange peels, etc.

test was conducted on Thursday and two on Friday. The sampling train and analytical procedures used are described in "Specifications for Incinerator Testing at Federal Facilities".[5] The sampling procedures specified in this publication were modified to fit the sampling situation presented by this incinerator.

The procedures used in this study are as follows: The top cross section of the unit was divided into three equal-area sections containing 12 smaller equal areas (Figure 2). Three sampling trains operating simultaneously (one for each of the three major sections) sampling in all 36 small areas comprised one test. For test number one, an actual sampling time of five minutes per point was used and each point was sampled twice. Within each section, the 12 points were sampled on a random basis. For test number two, a time of four minutes per point was used and each point was sampled once. For test number three, a time of four minutes per point was used and each point was sampled twice. Whenever a sampling train moved from one port to another, all trains were shut down until all were ready to begin sampling. The down time resulting from this method of testing was greater than the sampling time. To minimize the down time during test numbers two and three, the ports and the four points within a port were sampled on a random basis rather than all points being sampled on a random basis. Thus on these two tests all the points within a single port were sampled before a train was moved to another port.

During the tests, whenever excessive accumulations of particulate on the filters hindered isokinetic sampling, the filters were replaced

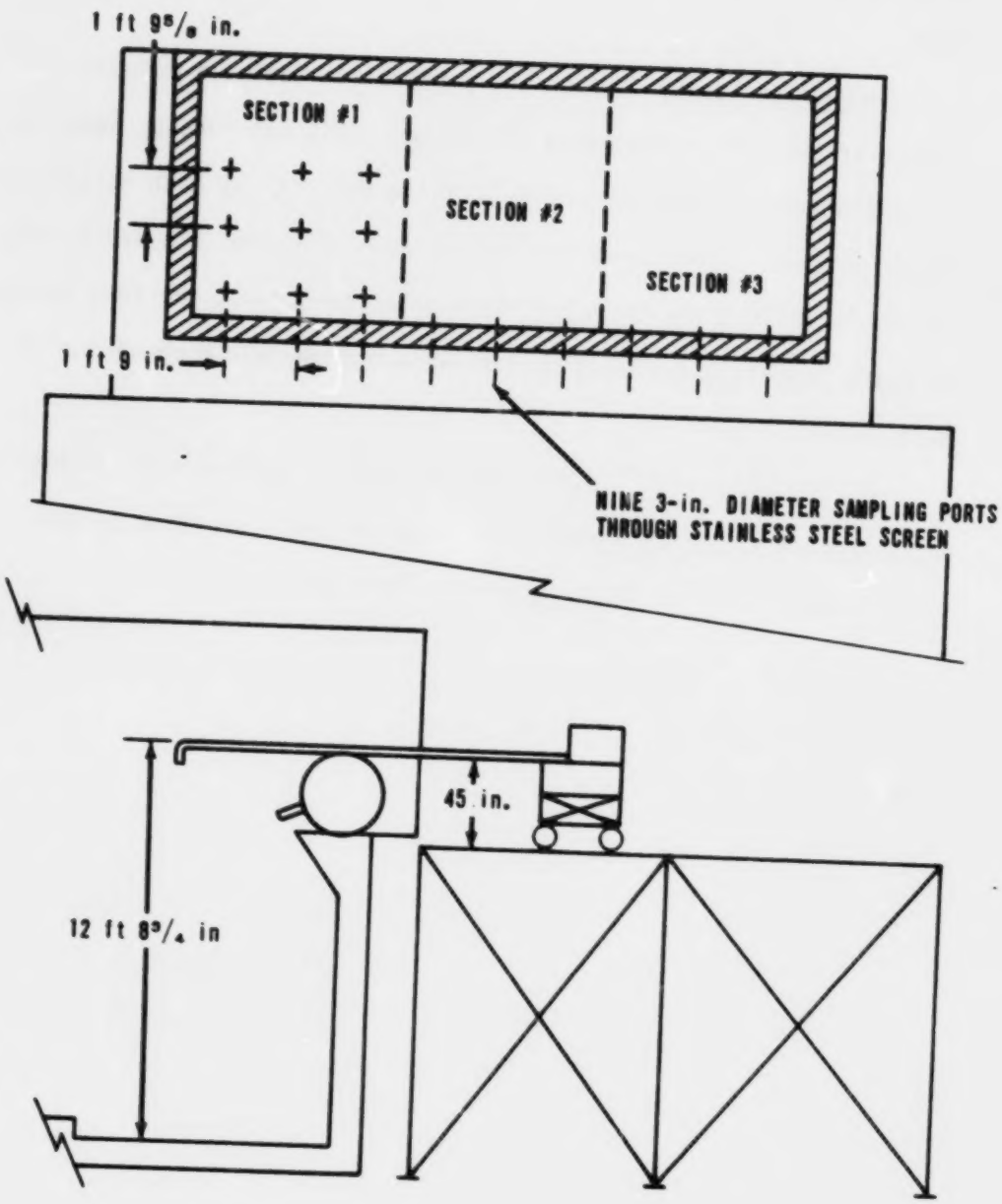

Figure 2. Method of sampling for air pollutants.

and the test continued to completion. Whenever negative gas velocities were encountered, the train was kept sampling but at its lowest possible rate.

Combustion Gases. During the particulate tests, a composite sample of the combustion gases was taken. This was done by sampling proportionately according to the positive velocity at each particulate sampling point. This composite sample was collected in a Tedlar bag by slowly filling the bag with stack gases throughout the test period. An Orsat Apparatus was used to determine the dry gas composition of this sample.

Visible Emissions. During the periods of testing the visible emissions were read by a certified smoke observer provided by the South Carolina Air Pollution Control Authority.

RESULTS

This section presents the data obtained from the analyses of samples taken during the field study of the pit incinerator. A test report prepared by Thermal Research and Engineering Corporation is presented in Appendix A. It contains a log of the operation and some general comments about the test.

Solid Waste

The amount of solid waste processed and the amount of residue removed during the study is shown in Table 1. The physical composition data (Table 2) were calculated on an "as received" basis. The densities were calculated on a wet basis as sampled from the storage area. The values for samples No. 1 through 3 are 120, 180, and 110 lb per cu yd, respectively.

The moisture content of the solid waste was obtained from the analysis of the whole sample, while the volatile, ash, and heat content were obtained from the analyses of only the combustible portion. The results (Table 3) were calculated for the complete sample on the assumption that the noncombustibles contained no heat or volatile material. The ash and volatile fractions were calculated on a dry basis. The heat and moisture contents were calculated on an "as received" basis. The methods for calculating these data are presented in Appendix B.

The data from the ultimate analyses of the solid waste (Table 4) were adjusted to an "as received" basis by assuming that each sample contained only eight constituents, the six listed plus ash and moisture. The results were accordingly adjusted on a weight basis to 100 percent.

TABLE I

SOLID WASTE PROCESSED

Item	Particulate test number			
	First day		Second day	
	Preliminary	Test No.1	Test No.2	Test No.3
Solid waste burned (lb)	20,100	24,400	19,550	14,350
Pallets (lb)	800	0	840	0
Burning time (hr)	11.4		5.0	
Burning rate (tons/hr)	2.0		3.5	
Residue (ton)	2.2		3.9*	

*This includes an estimated 3.4 tons of slag.

TABLE 2

SOLID WASTE COMPOSITION

Component	Sample number 1 (lb)	1 (%)	2 (lb)	2 (%)	3 (lb)	3 (%)	Average Percent
Combustibles:							
Food	13.0	4.5	51.2	8.2	43.3	20.3	11.0
Garden	10.0	3.5	4.5	0.7	13.7	6.4	3.5
Paper	158.0	55.2	409.0	65.8	88.5	41.5	54.2
Plastic, rubber leather	9.8	3.4	18.3	2.9	5.2	2.4	2.9
Textiles	8.0	2.8	13.2	2.1	1.0	0.5	1.8
Wood	0.5	0.2	6.5	1.1	0.3	0.2	0.5
Subtotal	199.3	69.6	502.7	80.8	152.0	71.3	73.9
Noncombustibles:							
Metal	49.7	17.4	58.5	9.4	22.0	10.3	12.4
Glass and ceramics	29.2	10.2	58.0	9.3	34.2	16.0	11.8
Ash, rocks, and dirt	8.0	2.8	2.8	0.5	5.0	2.4	1.9
Subtotal	86.9	30.4	119.3	19.2	61.2	28.7	26.1
Total Sample	286.2	100.0	622.0	100.0	213.2	100.0	100.0

TABLE 3

PROXIMATE ANALYSIS OF SOLID WASTE

Sample Number	Day of Operation	As sampled		Dry basis	
		Moisture (%)	Heat (Btu/lb)	Volatiles (%)	Ash (%)
1	First	30.1	3,440	55.6	44.4
2	Second	25.4	4,070	67.8	32.2
3	Second	23.3	4,270	60.7	39.3
Average*		24.4	4,170	64.2	35.8

*Second day of operation only.

TABLE 4

ULTIMATE ANALYSIS OF SOLID WASTE

Sample Number	Carbon (%)	Hydrogen (%)	Oxygen (%)	Nitrogen (%)	Sulfur (%)	Chlorine (%)
1	19.3	1.1	17.9	0.3	0.1	0.1
2	24.0	3.9	22.8	0.3	0.1	0.2
3	24.6	2.6	18.9	0.7	0.1	0.2

Residue

The data from the residue separation (Table 5) are on an "as sampled" basis (essentially a dry basis). The majority (about 87 percent) of the residue from the second day's operation was in the form of a slag. The residue sample (No. 2) was taken only from the loose material lying above this slag.

On a weight basis, the loose material was mainly fines and glass with few pieces of metal or tin can, although most of the volume was occupied by tin cans. There were some chunks of agglomerated residue in this loose material but these were easily broken apart.

The slag was hard, dense material. It was not layered but seemed to be a mixture of material fused together. There were identifiable tin cans, glass, wood charcoal, and in some instances, ashed newsprint in the slag. Although the slag did not contain free fines, it did contain small particles fused together.

The densities of the residue samples were calculated on an as sampled basis. The values for samples No. 1 and 2 are 1,190 and 1,090 lb per cu yd, respectively. The slag had a density of 4,370 lb per cu yd.

The moisture content, volatile, ash, and heat content were obtained from the analyses of only the fines and unburned combustible portions The results (Table 6) were calculated for the complete sample with the assumption that the glass and metal contained no heat or volatile material and no moisture. The ash and volatile fractions and the heat content were calculated on a dry basis. Example calculations are presented in Appendix C.

TABLE 5

RESIDUE COMPOSITION

Component	Sample number			
	1		2*	
	(lb)	(%)	(lb)	(%)
Glass, rocks, bricks	59.5	50.2	45.0	53.1
Metal	17.8	15.0	13.0	15.3
Unburned combustibles	1.7	1.5	trace	0.0
Fines	39.5	33.3	26.8	31.6
Total	118.5	100.0	84.8	100.0

*Sample taken from loose material above the slag; residue was about 13 percent loose and 87 percent slag.

TABLE 6

PROXIMATE ANALYSIS OF RESIDUE

Sample Number	As sampled	Dry basis		
	Moisture (%)	Heat (Btu/lb)	Volatiles (%)	Ash (%)
1	0.8	70	0.8	99.2
2*	0.0	60	0.0	100.0
slag	0.0+	0+	0.0+	100.0+

*Sample taken from loose material above the slag.

+Assumed.

The data from the ultimate analyses of the residue (Table 7) were adjusted to a dry basis by assuming that each sample contained only seven constituents the six listed plus ash. The results were accordingly adjusted on a weight basis to 100 percent.

Air Pollution Emissions

The data on particulate emissions and gas composition are probably not valid because of the sampling problems encountered during the study (see Discussion).

The visible emissions (percent opacity - visibility reduction) recorded by the South Carolina Air Pollution Control Authority are shown in Table 8. The readings shown in Table 8 were taken when waste was not being charged. The opacity readings increased when a charge was added to the furnace; as high as 70 percent the first day of tests and as high as 50 percent the second day.

Plant Efficiency

An indication of the plant's performance was obtained by calculating the percent volatile reduction, the percent heat released, and the percent volume reduction (Table 9). Example calculations are shown in Appendix D.

TABLE 7

ULTIMATE ANALYSIS OF RESIDUE

Sample Number	Carbon (%)	Hydrogen (%)	Oxygen (%)	Nitrogen (%)	Sulfur (%)	Chlorine (%)
1	1.5	0.0	0.6	0.1	0.1	0.1
2*	0.4	0.0	0.1	0.1	0.1	0.0

*Sample taken from loose material above the slag.

TABLE 8

VISIBLE EMISSIONS

May 7, 1970		May 8, 1970	
Time	Percent opacity	Time	Percent opacity
2:00 p.m.	0	1:00 p.m.	5
2:15	5	1:16	5
2:26	30	1:30	10
2:45	10	1:45	15
3:00	45	2:00	15
3:15	30	2:15	10
3:30	25	2:30	15
3:45	20	2:45	10
4:00	20	3:00	15
4:15	30	3:15	--
4:30	45	3:30	20
4:44	50	3:45	15
5:00	10	4:00	25
5:14	25	4:16	10
5:30	20	4:30	15
5:45	10	4:45	20
6:00	30	5:00	5
6:16	10	5:15	20
6:29	25	5:27	40
6:45	20	5:45	15
7:00	20	6:01	10
7:14	5		
7:29	5		
7:45	10		

TABLE 9

PLANT EFFICIENCY

Type of efficiency	Percent efficiency	
	First day of operation	Second day of operation
Reduction in volatiles	99.8	100.0
Reduction in heat content	99.8	99.7
Volume reduction	99.0	99.0

DISCUSSION

As indicated by the operating characteristics (Table 10), the operation of the unit during the first day was different from that during the second day.

TABLE 10

GENERAL OPERATING CHARACTERISTICS

Item	Day 1	Day 2	
		Test 2	Test 3
Air Nozzle angle (degree)	34	27	27
Charging rate (tons per hr)	2.0	3.5	3.5
Average temperature at sampling points (F)	170	430	585
Average gas velocity at sampling points (ft/min)	350	300	320
Fan draft (in. water gauge)	7.7	7.6	7.6
Visible emissions (percent opacity)	10-50	5-15	5-40

The average temperature and velocity data (Figure 3) tend to show the variable nature of the pit incinerator. The center section of the unit was the hottest and as the charging rate increased with successive particulate tests, the temperature also increased.

Only the vertical component of the velocity was measured at each point. Both positive and negative velocities were experienced, but no definite patterns were found.

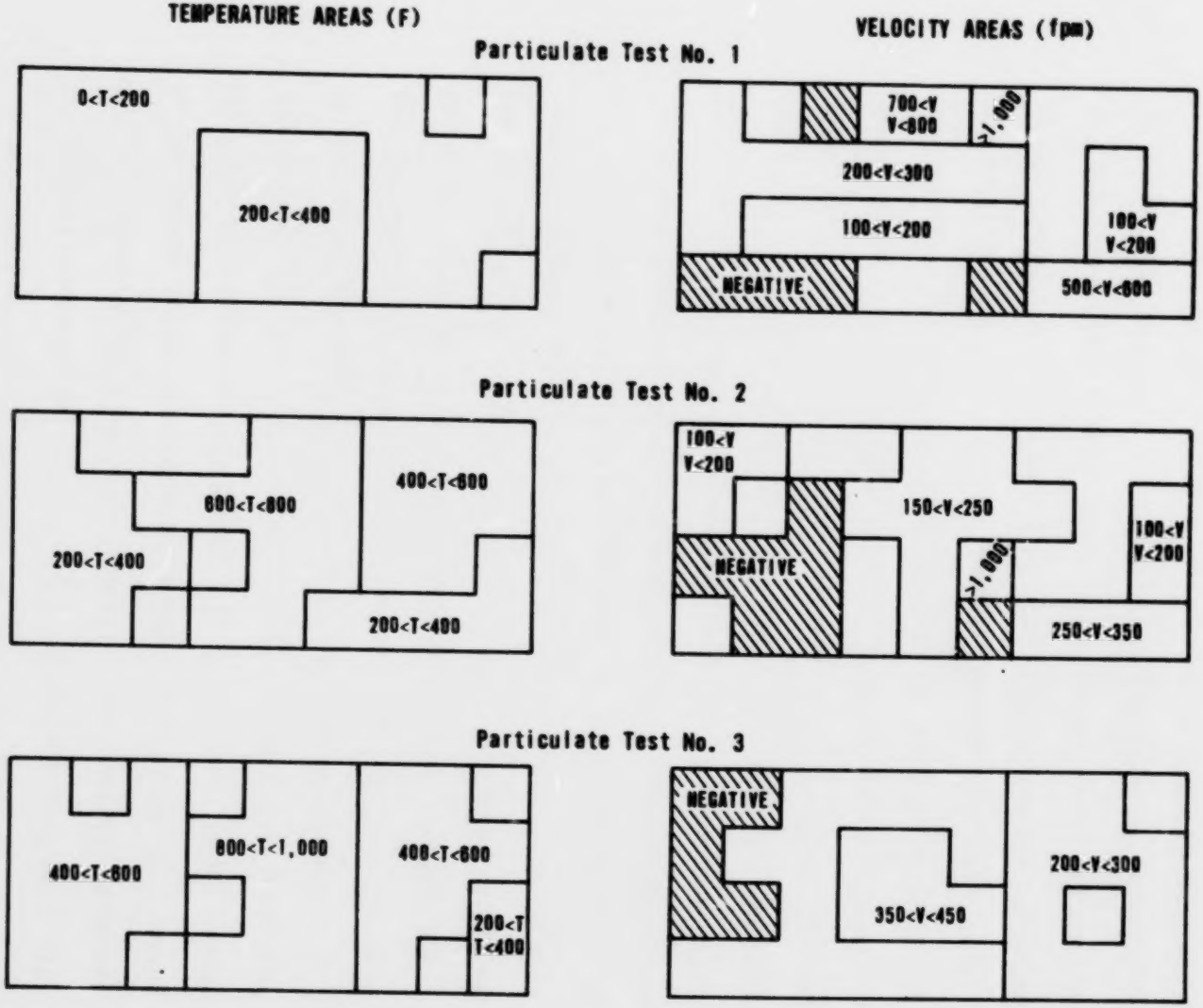

Figure 3. Average gas temperature and velocity data during particulate tests.

Reducing the angle of the overfire air nozzle from 34° to 27° had the following effects: (1) It did not alter the ability of the unit to incinerate solid waste efficiently. For practical purposes, no distinction can be made between the efficiency of the unit during the first day compared to the second day, in all cases being greater than 99 percent. (2) It did affect the rate at which the unit could incinerate solid waste. During the first day the unit burned 2.0 tons per hr and the second day it burned 3.5 tons per hr. (3) It also had an effect on the visible emissions. During the first day the opacity varied from 10 to 50 percent when waste was being burned and reached a maximum value of 70 percent during charging. (4) It did not affect the relationship between material caught behind the filter in the sampling train and the material caught in front of the filter (this information could be a possible indicator of combustion efficiency). For particulate test number one, 30.4 percent of the total was caught after the filter, test number two resulted in 33.5 percent, and test number three resulted in 30.0 percent. (5) From personal observations, the change in air nozzle angle did affect the quantity of large fly ash particles emitted to the atmosphere. On the first day, large quantities of big fly ash particles were emitted from the incinerator and deposited over the surrounding area. On the second day the quantity of these large particles was greatly reduced. This trend, while obvious to the members of the test team, was not shown in the particulate emission data (Table 11).

TABLE 11

PARTICULATE EMISSION DATA BASED ON MEASURED

PARTICULATE CONCENTRATIONS AND GAS COMPOSITION

Test no.	Sampling time (min)	Average CO_2 content in combustion gases %	Gas temperature (F)	Excess air (%)	Gas flow rate scfm	Gas flow rate acfm	Particulate emissions gr/scf at 12% CO_2	Particulate emissions lb/1,000 lb at 50% excess air	Particulate emissions lb/hr	Particulate emissions lb/ton waste
1	120.0	0.3	170	8,700	26,000	31,000	1.4	3.5	6.5	3.3
2	48.5	0.4	430	4,300	13,000	23,000	3.4	6.8	19.5	5.6
3	96.0	1.2	580	1,400	12,000	24,000	0.9	1.8	13.8	3.9

The measured particulate concentration (gr/scf and lb/1,000 lb) are erratic leading one to suspect that the gas composition data used to calculate the reported values might be in error (sampling problems were encountered during the collection of the gas composition samples). The emissions in terms of lb per hr and lb per ton, which do not include gas composition adjustments, also indicate that the unit emitted more particulate the second day than the first day which also leads one to question the validity of the particulate data.

In addition, the following observations about the test are offered: (1) Particulate sampling was known to be anisokinetic. The magnitude of the velocity pressure was small requiring the use of micro-manometers for detection. The velocity pressure fluctuated considerably and rapidly, frequently changing from positive to negative and back again. The temperature also fluctuated considerably. These fluctuations in velocity and temperature were too rapid to allow the sampling personnel to adjust sampling flow rates to maintain isokinetic conditions. (2) During charging, the probes had to be removed from the gas stream to protect them from physical damage. Thus, the particulates generated during the charging process were not sampled. The visibility data (Table 8) indicate that the particulate emissions were highest during this critical period. The charging period was about one minute out of every four minutes and was obviously a significant time span during which samples were not being collected. (3) Because the PHS particulate sampling train was used (the sample nozzle diameter is small, 3/8 to 3/4 in.), the large sized fly ash particles may not have been caught

by the sampling train. (4) The air pollution measurements were made near the exit of the incinerator and should have been esentially monitoring the products of combustion. There undoubtedly was some air infiltration occurring through the incinerator walls and at the top of the unit due to the wind. However, it is inconceivable that such infiltration could more than double the quantity of gases provided by the fan as would be the case if the measured flows from the first test are correct (Table 12).

TABLE 12

VOLUMETRIC GAS FLOWS

Test	Measured (scfm)	Provided by fan (scfm)
1	26,000	10,000
Average of 2 and 3	12,500	10,100

Based on the observations in the three paragraphs above, the particulate emissions are probably in error. To assist the reader in forming his own conclusions regarding the validity of the air pollution data, the field and laboratory data sheets are presented in Appendix E.

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Members of the field study team from the Solid Wastes Office were:

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Sample analyses were performed by Israel R. Cohen, James U. Doerger, and Donald L. Wilson of the Division of Research and Development, Solid Waste Management Office.

APPENDIX A

May 27, 1970

THERMAL RESEARCH & ENGINEERING CORP.

TEST REPORT

PURPOSE

To advise and assist the Federal Bureau of Solid Waste Management in running the Thermal Pit Incinerator located at the Monsanto plant, Greenwood, S. C.

The Bureau requirements are to run the incinerator on typical municipal refuse and garbage for a series of emission tests generally spelled out in the protocol dated April 27, 1970 issued by the Bureau.

DESCRIPTION OF INCINERATOR

The incinerator is a Model 16-H, generally as shown on Thermal Bulletin #138. It is lined with hollow refractory block filled with castable refractory. A 60 HP motor drives a 17700 CFM fan rated at 13.6" W.C. The incinerator has both over and underfire nozzles with a manually operated air damper located between the fan and the take off of the air for the lower nozzles. The lower air nozzles also have a manually operated valve.

Two cleanout doors are located at opposite ends of the incinerator, and a high temperature stainless steel wire mesh cage (1/4" mesh) encloses the top of the incinerator to prevent fly ash escaping to the atmosphere. Two manually operated barn-type loading doors are located on the front side of the mesh cage.

Present: L. Daniels - Bureau of Solid Waste Management
W. Achinger - Bureau of Solid Waste Management
G. Hammond - Plant Engineering - Monsanto Corp., Greenwood
T. Lucier - Thermal Research
T. Hawkes - Trecan

May 6, 1970 - Arrived at plant at noon - met Bureau and Monsanto personnel. Inspected the unit after lunch, refractory on right hand cleanout door was damaged - made arrangements to have this repaired. Checked the angle of the top header nozzles which hit target points on the front wall varying from 45" to 72" down from the top edge. This is lower than we would normally use for municipal garbage but decided to run the unit with this setting as changing would involve quite a lot of work.

Several of the underfire nozzles were plugged with nylon (from normal plant use); most were unplugged but several had to be left.

The screened loading door would not close properly at the top and also did not meet in the middle - fly ash would emit from these gaps. (Monsanto has subsequently re-designed and rebuilt the cage and doors.)

Evening: Met with L. Daniels and W. Achinger to discuss and plan Thursday's running.

May 7, 1970 - Garbage was delivered, 22,700 lbs. in a temporary fence enclosure erected for the purpose. This material appeared very wet and consisted of cafeteria waste, household garbage, hospital and doctors' office waste. There were boxes of vegetables, empty juice cans, etc. A quick density check was made and turned out to be approximately 15 lbs/ cu.ft.

Apparently this garbage had been collected Tuesday and Wednesday when it had rained, and was held over for this test.

Another 24,400 lbs. was delivered, which had been collected today. This was dryer but still contained pick-up from most the same places as the 22,700 lbs.

The front end loader arrived and it was established the bucket would hold approximately 2 cubic yards per load.

10:30 - Due to the garbage being rather wet we decided to start the incinerator on wooden pallets. 10 weighing 804 lbs. were loaded plus 2 buckets of boxes and paper from the garbage in the wire cage.

Time A.M.	Loads	Air Press.	Lower Valve Setting	
10:45	2	6"W.C.	1/2	Not burning too good.
11:05	2	6"W.C.	1/2	Still not burning well, steam for 2 mins.
11:15	2	8"W.C.	Full Open	Still not burning properly, lots of steam for 2 mins.
11:45	3	8"W.C.	Full Open	Burning appears to get smothered, blow holes break through.
12:05	3	3"W.C.	Full Open	Still not working correctly. Front end loader not dumping at rear of unit, reach is not long enough.
12:30		5"W.C.	Full Open	Unit just smoldering - not right.
1.00		12"W.C.	Full Open	Went to lunch - left air at 12" W.C.
1:55		12"W.C.	Full Open	Returned from lunch, pile had burned down in pit.
1:55	2	6"W.C.	Full Open	2 loads of cardboard and wooden boxes, from 24,400# pile. Continuous for the rest of the day from this pile.
2:00	1	6"W.C.	Full Open	1 load dry garbage.
2:05	2	8-1/2"W.C.	Full Open	
2:10	1	8-1/2"W.C.	Full Open	Unit still not working correct - flames still smothered.
2:25	2	7-1/2"W.C.	Full Open	
2:35	2	7-1/2"W.C.	Full Open	Left unit to burn down bed of residue.
3:20	2	7-1/2"W.C.	Full Open	Still not working correctly.
3:40	2	7-1/2"W.C.	Full Open	
3:55	2	7-1/2"W.C.	Full open	Still no good. Went and had coffee.

Time	Loads	AirPress.	Valve Setting	
4:20				Returned from coffee - bed had burned down again.
4:20	1	8"W.C.	Full Open	Unit burning a little better- lots of fly ash (too high air press.)
4:35	1	6"W.C.	Full Open	better
4:40	1	6"W.C.	Full Open	better, less fly ash, this lower feed rate appears better.
4:55	1	7"W.C.	Full Open	Flame ragged, - still burning better, but do not have the rolling flame
5:05	1	7"W.C.	Closed	Flame ragged,-but burning better than this morning.(note: this garbage is dryer).
5:15	1	7"W.C.	Closed	
5:20	1	6"W.C.	closed	smoking a little-so will open underfire air
5:21	1	6"W.C.	Open	smoke clears
5:25	1	6"W.C.	Open	
5:40	1	6"W.C.	Open	
5:45	1	6"W.C.	Open	This rate of feed appears best to date
5:55		9"W.C.	Open	Raised air to 9" to try and eliminate smothering effect.
6:00		9"W.C.	Open	Poor burning
6:05		9"W.C.	Open	Still poor burning
6:05	1	8"W.C.	Open	Burning a little better.
6:10	1	8"W.C.	Open	burning a little better.
6:20	1	8"W.C.	Open	
6:30	1	8"W.C.	Open	
6:35	1	8"W.C.	Open	300° recorded above header.
6:43	1	8"W.C.	open	
6:47	1	8"W.C.	open	
6:55	1	8"W.C.	open	600° recorded above header - burning better but not proper.
6:59	1	8"W.C.	open	
7:01	1	8"W.C.	open	
7:03	1	8"W.C.	open	Unit is burning much better - it may have been that we were starving it of material.
7:05	1	8"W.C.	open	
7:07	1	8"W.C.	open	
7:10	1	8"W.C.	open	
7:11	1	8"W.C.	open	
7:13	1	8"W.C.	open	
7:15	1	8"W.C.	open	
7:17	1	8"W.C.	open	
7:19	1	8"W.C.	open	
7:20	1	8"W.C.	open	

Time	Loads	Air Press.	Valve Setting	
7:22	1	8"W.C.	Open	Bureau checked Density of garbage 4½ lbs/cu ft. loose.
7:23	1	8"W.C.	Open	
7:24	1	8" W.C.	Open	
7:26	1	8" W.C.	Open	
7:27	1	8" W.C.	Open	Unit still burning better, but with very ragged flame pattern.
7:28	1	8" W.C.	Open	
7:30	1	8" W.C.		
7:32	1	8" W.C.	Open	
7:35	1	8" W.C.	Open	
7:37	1	8" W.C.	Open	
7:38	1	8" W.C.	Open	
7:39	1	8" W.C.	Open	
7:40	1	8" W.C.	Open	
7:41	1	8" W.C.	Open	
7:43	1	8" W.C.	Open	
7:45	1	8" W.C.	Open	Unit burning ragged but much better.
7:48	1	8" W.C.	Open	Clean up remains of 24400 pile
7:51	1	8" W.C.	Open	Clean up
8:00				24,400 pile finished.Cleaned up and left blower on 8" W.C. till next morning.
				Decided to rotate top header and obtain new angle of nozzle. This work to be carried out AM tomorrow.

May 8th, 1970. - Arrived at site 8:30.
Cleaned out residue, approximately 2½ ft. deep in pit. Started rotating headers, to hit target of 39" nominal.

Four loads of garbage arrived and was put into two separate piles, one being 19,500 lbs and the other 14,450 lbs.

Clean out complete and nozzle rotation complete. Did a weight check of 2 cu. yds of todays material - 298 lbs/2yds.

Todays garbage came from similar pick-ups as before, but in both piles we found a cluster of automobile tires. These clusters were removed, took 19 out of the 19,500 lb load and 9 out of the 14,450. There were several other tires in the garbage pile, these were left in. Three 45 gallon steel drums were also removed.

We also removed the 12" I Beam from in front of the pit on the loading side to enable the front end loader to reach farther across the pit when loading, even so we still do not reach far enough.

Weighed out 12 wooden pallets - 842 lbs. Loaded 12 pallets, some cardboard and started unit, allowed pallets to burn up and get a good base fire.

(over)

Time	Loads	Air Press.	Valve Setting	
12:40		6"W.C.	3/4 open	Started blower - very good rolling flame.
12:45	2	6"W.C.	3/4	Loading from 19 500 pile - very good.
12:50	2	6"W.C.	3/4	Bureau Started Tests. no smoke. some fly ash through broken screen.
12:55	2	6"W.C.	3/4	
1:00	2	6"W.C.	3/4	
1:05	2	6"W.C.	3/4	power went off Bureau test equipment.
1:12	2	6"W.C.	3/4	45 gallon drum removed from loader.
1:20	2	6"W.C.	3/4	Power back on.
1:25	2	6"W.C.	3/4	Very good burning - take air to 0" W.C. when loading
1:33	2	6"W.C.	3/4	600° over header, 1800° in pit (optical pyrometer) two tires loaded.
1:40	2	6"W.C.	3/4	smoking during loading and running. (Tires?)
1:45		10"W.C.	3/4	smoke eliminated, poly loaded with trash.
1:50	1	10"W.C.	3/4	smoke at loading, (From poly?)
1:50				Bureau test equipment damaged - asked to slow down incinerator.
1:58				Unit repair - carry on testing
2:00	2	6"W.C.	3/4	burning good 400-500° at header.
05	2	6"W.C.	3/4	
2:10	2	6"W.C.	3/4	
2:15	2	6"W.C.	3/4	
2:20		10"W.C.	3/4	unit smoking, must have loaded a tire - press. raised to 10" W.C.
2:21		10"W.C.	3/4	Smoke cleared.
2:25	2	10"W.C.	3/4	
2:30	2	6 "W.C.	3/4	Bureau test complete - 1/2 hr burning left in 19,500 lb pile
2:30				Stopped burning from 19,500 lb pile, kept incinerator going from pile in Wire pen. Left unit to run on without further loading to reduce pile in pit.
2:48	2	10"W.C.	3/4	From wire pen.
3:00	2	6 "W.C.	3/4	From wire pen.
3:15	2	6 "W.C.	3/4	From wire pen.
3:30				New test to start from 14,450 # pile.
3:35	2	6 "W.C.	3/4	Good base fire several blow holes bed approx. 2' deep in centre.
3:40	2	6 "W.C.	3/4	Commercial waste, plastics rubber, fire better.
3:45	2	10"W.C.	3/4	more commercial, some smoke at 6" W.C.
3:50	2	10"W.C.	3/4	smoke during loading -(commercial matl?)
3:55	2	10"W.C.	3/4	loading smoke now reduced.

Time	Loads	Air Press	Valve Setting	
4:03	2	10"W.C.	3/4	More plastic-black smoke during loading - 625°F at header.
4:10	2	10"W.C.	3/4	Excellent rolling flame. very near nozzle.
4:13	2	10"W.C.	3/4	Flame now dropped down in pit.
4:15	2	6 "W.C.	3/4	No smoke at loading.
4:20	2	7 "W.C.	3/4	Very hot to open & close doors, now wearing face masks.
4:30	2	6 "W.C.	3/4	Good fire, slight smoke last 15 mins. can smell burning rubber.
4:30	2	6 "W.C.	3/4	Slight smoke during loading-good fire.
4:40	2	6 "W.C.	3/4	Excellent rolling flame.
4:45	2	8 "W.C.	3/4	Excellent rolling flame, temps at the header up to 1000° in some places
4:50	2	7 "W.C.	3/4	Excellent rolling flame,
4:57	2	7 "W.C.	3/4	Excellent rolling flame,
5:03	2	7 "W.C.	3/4	Excellent rolling flame, temp at header up to 1400°F.
5:10	2	7 "W.C.	3/4	
5:17	2	7 "W.C.	3/4	Flame swirling a little
5:25	2	6 "W.C.	3/4	
5:30	2	6 "W.C.	3/4	
:35	2	6 "W.C.	3/4	Good rolling flame (up around nozzle)
5:40	2	6 "W.C.	3/4	Sampling by Bureau complete - requested to burn off all garbage left including that in the pen. 5 bucket loads left from the 14,450lb. load.
5:45	2	6 "W.C.	3/4	
5:52	2	6 "W.C.	3/4	
5:57	2	6 "W.C.	3/4	
6:07	2	9 "W.C.	3/4	3 boxes rubber 16x16x24 all went in at once - slight smoke.
6:12	2	9 "W.C.	3/4	2 more boxes shredded rubber.
6:17	2	9 "W.C.	3/4	2 more boxes shredded rubber and 2 tires good rolling flame.
6:30	2	9 "W.C.	3/4	2 more tires in
6:35	2	10"W.C.	3/4	2 more tires in. Have completed burning from 14,400 lb and 19,500 # loads, now working from wire pen.
6:40	1	10"W.C.	3/4	Flat tire on loader - approx 12 loads left in wire pen
7:05				New loader arrived - 2 yd bucket
7:10	3	7"W.C.	3/4	Poor flame pattern - driver went for gas
7:20	3	7"W.C.	3/4	Poor flame pattern-
7:26	3	7"W.C.	3/4	Poor flame , no smoke - very high bed
7:36	1	10"W.C.	3/4	Poor flame .

Time	Loads	Air Press.	Valve Setting	
7:38	1	10"W.C.	3/4	Poor flame.
7:40	1	10"W.C.	3/4	Good fire - 1/2 rolling fire, very hot flame.
7:42	1	10"W.C.	3/4	Good fire.
7:44	1	10"W.C.	3/4	
7:45	1	10"W.C.	3/4	
7:46	1	10"W.C.	3/4	All garbage gone, test complete.

GENERAL COMMENTS

Conditon and design of the Monsanto pit depart from our standard approach for municipal installations in several ways:

1. The top air header nozzles were distorted vertically and horizontally by heat from burning high heat release plastic wastes. When burning plastics the nozzles are normally set at a lower angle than for municipal wastes. On our initial check at Monsanto we found the nozzles were aimed at target points on the opposite wall varying from 45" to 72" down from the top edge. The first test run, May 7, was performed with the nozzles in this position.

   Prior to the test runs May 8, the nozzles were raised to target settings of 34" to 54", which almost certainly contributed to the better performance on tests 2 and 3. Experimentation elsewhere on municipal installations has demonstrated that the optimum target setting is about 39" from the top edge. The nozzle angle has an important bearing on the combustion characteristics and the achievement of the rolling flame pattern which is essential to optimum performance.

2. An important purpose of underfire air in municipal operation is to supply combustion air to the pit while the overfire air supply is cut off for charging. The design of the Monsanto pit is such that the tap for the underfire manifold is downstream of the main blower damper. Thus, when the overfire air is cut for charging, the underfire air supply is likewise stopped.

3. The barn-type loading doors in the screen cage over the pit were distorted and damaged from the heat of burning nylon. When closed, they gapped at the top and middle and fly ash escaped from these openings. This condition was worse for tests 2 and 3 on Thursday, when the top latch became inoperable. When burning large amounts of paper and cardboard a tight screen is mandatory to contain fly ash (this has no bearing, of course, on the emission tests which were taken inside the screen enclosure).

4. Several of the underfire air nozzles were plugged with nylon. A few remained plugged or partially obstructed during the tests.

5. Design of the retaining wall in front of the pit prevents the front end loader from placing the loads accurately in the pit, due to insufficient reach. This problem does not exist at the Canadian municipal pit instalations and our (U.S.) standard design was changed some time ago to eliminate the concrete obstruction.

6. The standard municipal pit design includes motor-operated blower damper and loading door, remotely controlled from the loading platform. Probably this equipment does not significantly affect the burning rate or characteristics, but it greatly facilitates the loading operation.

Sampling techniques used in the tests were devised by the Bureau. Probes were traversed across the pit on a plane just over the main air manifold. This approach was meant to minimize the effect of inspirated air and to provide readings more nearly equivalent to a conventional stack test. At this writing the results have not been reported and any judgment as to the efficacy of the test procedure awaits subsequent analysis.

What was apparent was that a large amount of fly ash -- principally small pieces of burned paper -- circulates inside the screen without escaping to the atmosphere. Thus, the particulate readings obtained in the Bureau tests may not accurately represent the amount of material actually emitted from the unit. Most of this material settles to the ground near the incinerator.

Ringelmann readings exceed No. 1 only under very adverse operating conditions, and then only briefly. Few, if any, smoke readings exceed Ringelmann No. 2.

Results during the first day (May 7) were generally poor. The garbage was quite wet (a rough check indicated a density of about 15 lbs/cu.ft.) and appeared to contain a high proportion of non-combustibles. The average heat content was probably on the low end of the range for typical municipal refuse. We could not get a good, hot fire going and could not produce the characteristic rolling flame pattern. Varying feed rates and techniques were tried without particular success. Temperatures recorded by the Bureau over the manifold were generally under 200°F. Clouds of steam were emitted after each charge. When the pit is operating properly, water content of the garbage is quickly vaporized without visible emissions.

Later in the day, after the first sampling test was finished, the feeding rate was stepped up and the air setting was raised. By this time the residue in the pit had built up to a level over the cleanout door arches and the air pattern was ragged and whippy, rather than rolling. Because of this, and the high air setting, emission of fly ash increased visibly. Nevertheless we were getting a steady build-up of heat and a much improved burn.

For one period of about a half hour loads were being charged to the pit about as quickly as they could be brought up by the loader. This feeding rate, if sustained, would have put about forty loads/hr. into the pit. Each load held about 2 cu.yds. and a check the next day indicated a weight of about 300 lbs./load. On this basis the burning rate was about 6 tons/hr. Assuming the lesser density measured by the Bureau of about 5 lbs./cu.ft., the rate would be about 5 tons/hr.

Various conclusions might be drawn from the first day's run. It was apparent that the pit will effectively burn very wet garbage once a sufficient total heat build-up is achieved. Faster feed rates helped and it is possible the pit was being starved for Btu release earlier in the day.

On the second day (May 8) the unit performed much better -- everything considered, it was about what we expecton a typical day's run on municipal refuse. The material was drier and appeared to contain a somewhat higher proportion of combustibles. Because of the experience Thursday we were careful to start a good fire; the higher nozzle angle produced a noticeably improved flame pattern.

In 7 hours, including several periods of varying length when loading was deliberately slowed or stopped, we burned roughly 20 tons of refuse. During the sampling periods we aimed for a loading rate of 2 loads (4 cu.yds.) every 5 minutes. At the measured densities, this represents a rate of 3-1/2 to 4 tons/hr. No attempt was made to push the unit in terms of capacity, but the burning rate during tests 2 and 3 was consistent with our expectations for commercial operation of between 3 and 5 tons/hr., depending on the characteristics of the feed material.

Considerable amounts of commercial trash were fed to the pit during the afternoon, including some tires, quantities of sheet plastic and boxes of shredded rubber. From time to time this produced some smoke, particularly during charging, but usually the smoke cleared quickly when the air setting was raised.

After the two sampling tests were completed, and the two piles set aside for the tests were consumed (about 33,900 lbs. total) the material in the pit was left to burn with only intermittent charging for about a half hour or more. The loader had a flat tire and a second unit was located and put into service. Material left in the fence enclosure from the Thursday test was then cleaned out to complete the run. By this time the residue had built-up over the arches and the flame pattern was ragged. We then reverted experimentally to the loading pattern used with success near the end of Thursday's operation -- quick, single loads every 1 or 2 minutes with the air brought up to 10" W.C. after each charge. As was true Thursday, this finally produced a very hot although erratic fire.

On both nights after the tests the air was left on and the material allowed to burn down overnight before the cleanout the following morning. The residue from the Thursday run was mostly inert with a large quantity of tin cans, some fused glass and a few clinkers. The cleanout procedure was complicated by the lack of an adequate ramming tool. A small tractor was used to drag the material from the pit somewhat laboriously.

On Saturday morning the cleanout crew encountered a massive, monolithic "clinker" about 9" deep and covering the entire bottom below the flame step. Jackhammers were needed to break and dislodge it. A sample of this material has been received from Monsanto but an analysis has not yet been performed. We presently assume the mass was formed by fused glass and other melted substances acting as a binder for material on the bottom. A check of our municipal pit operations in Canada revealed no comparable experience although some fairly large clinkers containing fused material are encountered occasionally.

Temperatures over the manifold during tests 2 and 3 were markedly higher than those recorded during test 1.

APPENDIX B

Example Calculations for Results of Solid Waste Proximate Analysis

Using the data (Table B-1) from the laboratory analyses of solid waste sample No. 1, these example calculations show the methods used to calculate the moisture content, ash and volatile content, and the heat content of the total sample. The volatile and ash fractions and the heat content of the laboratory samples are on a dry basis. For these calculations, the noncombustibles were assumed to contain no heat and no volatile material. The field separation determined a paper content of 55.2 percent, a remaining combustible content of 14.4 percent and a noncombustible content of 30.4 percent (Table 2) on a wet basis.

TABLE B-1

PROXIMATE ANALYSIS OF SOLID WASTE SAMPLES

Sample no.	Component	Moisture (%)	Volatiles (%)	Ash (%)	Heat (Btu/lb)
1	paper	38.0	90.9	9.1	7,890
	other combustibles	36.7	84.7	15.3	8,100
	noncombustibles*	12.8	0.0	100.0	0
2	all combustibles	30.8	90.4	9.6	8,145
	noncombustibles*	2.9	0.0	100.0	0
3	paper	15.8	94.1	5.9	7,990
	other combustibles	51.6	94.9	5.1	10,205
	noncombustibles*	4.8	0.0	100.0	0

*Volatile, ash, and heat contents were assumed.

Moisture Content. The percent moisture in the total sample was calculated by the following method:

$$\text{Percent moisture in total sample} = \left[\left(\frac{\text{lb paper}}{\text{lb waste}}\right)\left(\frac{\text{lb moisture}}{\text{lb paper}}\right) + \left(\frac{\text{lb other combustibles}}{\text{lb waste}}\right)\left(\frac{\text{lb moisture}}{\text{lb other combustibles}}\right) + \left(\frac{\text{lb noncombustibles}}{\text{lb waste}}\right)\left(\frac{\text{lb moisture}}{\text{lb noncombustibles}}\right)\right] 100.0$$

$$\text{Percent moisture in total sample (No. 1)} = [(0.552)\ (0.38) + (0.144)(0.367) + (0.304)\ (0.128)]\ 100.0$$

$$\text{Percent moisture in total sample (No. 1)} = 30.1$$

Volatile and Ash Contents. Because the volatile and ash fractions are calculated on a dry basis, the percent combustibles and noncombustibles must be converted to a dry basis by means of the following equation:

$$\text{Percent dry component} = \left[\frac{\text{lb wet component} - \text{lb moisture in component}}{\text{dry sample weight}}\right] 100.0$$

$$\text{Percent dry paper in total sample (No. 1)} = \left[\frac{158.0 - 60.0}{200.05}\right] 100.0 = 49.0$$

These calculations are summarized in Table B-2.

TABLE B-2

CONVERSION OF THE COMBUSTIBLE AND

NONCOMBUSTIBLE DATA TO A DRY BASIS

Component	Wet weight (lb)	Moisture (%)	Moisture (lb)	Dry weight (lb)	Percent by dry weight
Paper	158.0	38.0	60.0	98.0	49.0
Other combustibles	41.2	36.7	15.1	26.1	13.1
Noncombustibles	87.0	12.8	11.1	75.9	37.9
Total	286.2	-	86.2	200.0	100.0

The percent of volatiles and ash may be calculated as follows:

$$\text{Percent volatiles in total sample} = \left[\left(\frac{\text{lb volatiles}}{\text{lb dry paper}}\right)\left(\frac{\text{lb dry paper}}{\text{lb dry waste}}\right) + \left(\frac{\text{lb volatiles}}{\text{lb dry other combustibles}}\right)\left(\frac{\text{lb dry other combustibles}}{\text{lb dry waste}}\right)\right] 100.0$$

$$\text{Percent volatiles in total sample (No. 1)} = [(0.909)\ (0.49) + (0.847)(0.131)]\ 100.0 = 55.6$$

$$\text{Percent ash in total sample} = 100.0 - \text{percent volatiles}$$

$$\text{Percent ash in total sample (Nb.1)} = 100.0 - 55.6 = 44.4$$

Heat Content. The laboratory reports the heat content on a dry basis for the combustibles only, thus the moisture content and the noncombustibles in the total sample must be accounted for when calculating the heat content of the total sample on an "as received" basis.

$$\text{Heat content of total sample} = \left[\frac{\left(\frac{\text{Btu}}{\text{lb dry paper}}\right)\left(\frac{\text{lb dry paper}}{\text{lb dry waste}}\right) + \left(\frac{\text{Btu}}{\text{lb dry other combustibles}}\right)\left(\frac{\text{lb dry other combustibles}}{\text{lb dry waste}}\right)}{\left(\frac{\text{lb dry paper}}{\text{lb dry waste}}\right) + \left(\frac{\text{lb dry other combustibles}}{\text{lb dry waste}}\right)}\right] \left[1 - \left(\frac{\text{percent moisture in combustibles} + \text{percent wet noncombustibles}}{100.0}\right)\right]$$

Where:

$$\text{Percent moisture in combustibles} = \left[\frac{\text{lb moisture in paper} + \text{lb moisture in other combustibles}}{\text{lb wet combustibles}}\right] 100.0$$

$$\text{Percent moisture in combustibles} = \left[\frac{60.0 + 15.1}{158.0 + 41.2}\right] 100.0 = 26.2$$

$$\text{Heat content of total sample} = \left[\frac{(7890)(0.49) + (8100)(0.131)}{0.49 + 0.131}\right] \left[1 - \frac{(26.2 + 30.4)}{100.0}\right]$$

$$\text{Heat content of total sample} = 3{,}440$$

APPENDIX C

Example Calculations for Results of Residue Proximate Analysis

Using the data from the laboratory analyses of residue sample No. 1 (Table C-1) these example calculations show the methods used to calculate the moisture content, ash and volatiles content, and heat content of the total sample. The volatile and ash fractions and the heat content of the laboratory samples are on a dry basis.

The amount of metal, glass, fines, and unburned combustibles found during the field separation was 15.0, 50.2, 33.3, and 1.5 percent respectively on a wet-weight basis (Table 5). For these calculations, the metal and glass were assumed to contain no heat, no volatile material, and no moisture.

Moisture Content. The percent moisture in the total sample was calculated by the following method:

$$\text{Percent moisture in total sample} = \left[\left(\frac{\text{lb metal}}{\text{lb residue}}\right)\left(\frac{\text{lb moisture}}{\text{lb metal}}\right) + \left(\frac{\text{lb glass}}{\text{lb residue}}\right)\left(\frac{\text{lb moisture}}{\text{lb glass}}\right) + \left(\frac{\text{lb fines}}{\text{lb residue}}\right)\left(\frac{\text{lb moisture}}{\text{lb fines}}\right) + \left(\frac{\text{lb unburned combustibles}}{\text{lb residue}}\right)\left(\frac{\text{lb moisture}}{\text{lb unburned combustibles}}\right)\right] 100.0$$

$$\text{Percent moisture in total sample (No. 1)} = [(0.15)\ (0.0) + (0.502)\ (0.0) + (0.333)(0.0) + (0.015)\ (0.56)]\ 100.0$$

$$\text{Percent moisture in total sample (No.1)} = 0.8$$

TABLE C-1

PROXIMATE ANALYSIS OF THE RESIDUE

Sample Number	Glass and metal	Unburned combustibles				Fines			
	Moisture* (%)	Moisture (%)	Volatiles (%)	Ash (%)	Heat (Btu/lb)	Moisture (%)	Volatiles (%)	Ash (%)	Heat (Btu/lb)
1	0.0	56.0	67.4	32.6	6,020	0.0	1.1	98.9	115
2	0.0	0.0	84.5	15.5	8,540	0.0	0.1	99.9	180

* Assumed

Volatile and Ash Contents. Because the remaining calculations are on a dry basis, the separation data from Table 5 must be converted to a dry basis by the following method:

$$\text{Percent dry component} = \left(\frac{\text{lb wet component} - \text{lb moisture in wet component}}{\text{total dry sample weight}}\right) 100.0$$

$$\text{Percent dry unburned combustibles in total sample (No.1)} = \left(\frac{1.7 - 1.0}{117.4}\right)100.0 = 0.6$$

TABLE C-2

CONVERSION OF THE RESIDUE DATA TO A DRY BASIS

Component	Wet weight (lb)	Moisture (%)	Moisture (lb)	Dry weight (lb)	Percent by dry weight
Unburned combustibles	1.7	56.0	1.0	0.7	0.6
Fines	39.5	0.0	0.0	39.5	33.6
Glass	59.5	0.0	0.0	59.5	50.7
Metal	17.8	0.0	0.0	17.7	15.1
Total sample	118.5	-	1.0	117.4	100.0

The percent of volatiles and ash may be calculated as follows:

$$\text{Percent volatiles in total sample} = \left[\left(\frac{\text{lb volatiles}}{\text{lb dry fines}}\right)\left(\frac{\text{lb dry fines}}{\text{lb dry residue}}\right) + \left(\frac{\text{lb volatiles}}{\text{lb dry unburned combustibles}}\right)\left(\frac{\text{lb dry unburned combustibles}}{\text{lb dry residue}}\right)\right]100.0$$

$$\text{Percent volatiles in total sample (No.1)} = [(0.011)(0.336) + (0.674)(0.006)]\ 100.0 = 0.8$$

$$\text{Percent ash in total sample} = 100.0 - \text{percent volatiles}$$

$$\text{Percent ash in total sample (No. 1)} = 100.0 - 0.8 = 99.2$$

Heat Content. The laboratory reports the heat content on a dry basis for the fines and unburned combustibles, and therefore, the heat content of the total sample on a dry basis is calculated as follows:

$$\text{Heat content of total sample on a dry basis} = \left(\frac{\text{Btu}}{\text{lb dry fines}}\right)\left(\frac{\text{lb dry fines}}{\text{lb dry residue}}\right) + \left(\frac{\text{Btu}}{\text{lb dry unburned combustibles}}\right)\left(\frac{\text{lb dry unburned combustibles}}{\text{lb dry residue}}\right)$$

$$\text{Heat content of total sample (No. 1) on a dry basis} = (115)\,(0.336) + (6{,}020)\,(0.006) = 70$$

APPENDIX D

Plant Efficiency Calculations

These example calculations show the methods used to calculate the percent reduction of volatile material, the percent heat released, and the percent volume reduction. The following data were used:

	First day of operation	Second day of operation
Solid waste:	22.6 tons (wet)	17.4 tons (wet)
	30.1 percent moisture	24.4 percent moisture
	15.8 tons (dry)	13.1 tons (dry)
	3,440 Btu per lb (wet)	4,170 Btu per lb (wet)
	55.6 percent volatiles	64.2 percent volatiles
	120 lb per cu yd (wet)	140 lb per cu yd (wet)
Residue:	2.2 tons (wet)	0.5 tons loose material (dry)
	0.8 percent moisture	3.4 tons slag (dry)
	2.2 tons (dry)	60 Btu per lb (dry)
	70 Btu per lb (dry)	0.0 percent volatiles
	0.8 percent volatiles	1090 lb per cu yd (dry)
	1190 lb per cu yd (wet)	4,370 lb slag per cu yd

Using the data for the first day of operation:

$$\text{Percent Volatile reduction} = \left[1 - \left(\frac{\text{volatile content of the residue} + \text{volatile content of the particulates*}}{\text{volatile content of the solid waste}}\right)\right] 100.0$$

$$\text{Percent volatile reduction} = \left[1 - \left(\frac{(2.2)\ (2{,}000)\ (0.008)}{(15.8)\ (2{,}000)\ (0.556)}\right)\right] 100.0$$

$$\text{Percent volatile reduction} = 99.8$$

$$\text{Percent heat release} = \left[1 - \left(\frac{\text{heat content of the residue} + \text{heat content of the particulates*}}{\text{heat content of the solid waste}}\right)\right] 100.0$$

*not measured

$$\text{Percent heat release} = \left[1 - \left(\frac{(2.2)\ (2{,}000)\ (70)}{(15.8)\ (2{,}000)\ (3{,}440)}\right)\right] 100.0$$

$$\text{Percent heat release} = 99.8$$

$$\text{Percent volume reduction} = \left[1 - \left(\frac{\text{volume of residue} + \text{volume of particulates}^{*}}{\text{volume of solid waste}}\right)\right] 100.0$$

$$\text{Percent volume reduction} = \left[1 - \left(\frac{\frac{(2.2)\ (2{,}000)}{1190}}{\frac{(22.6)\ (2{,}000)}{120}}\right)\right] 100.0$$

$$\text{Percent volume reduction} = 99.0$$

*not measured

APPENDIX E

Air Pollution Measurement Field Data

This appendix contains the velocity traverse data sheets, the particulate sampling train data sheets, and the laboratory analysis of the samples.

VELOCITY TRAVERSE DATA SHEET

Plant Pit Incinerator

Date 5-7-70

Test Number 1-1

Sampling Location Section No. 1

Wet Bulb Temperature, °F, T_{wb} 83

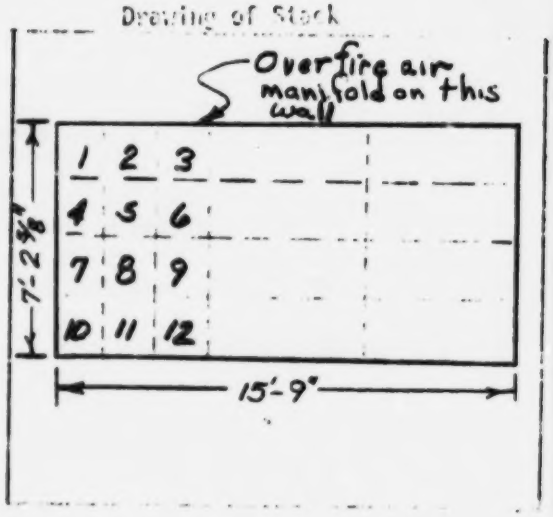
Dry Bulb Temperature, °F, T_{db} 67

Stack Gague Pressure, "H_2O 0

Stack Diameter

Operators

Drawing of Stack



Point No.	% of Dia.	Distance from inside Wall to Sampling Point (in)	Add Factor (in.)	Distance from Reference Point (in.)	Stack Temp., (°F)	Velocity Head or ΔP, ("H_2O) V	Comments
1-1	N.A.	75.81	60	135.81	88	-0.001	
1-4		54.15	60	114.15	95	0.001	
1-7		32.49	60	92.49	90	-0.008	
1-10		10.83	60	70.83	105	0.059	
1-12		75.81	60	135.81	80	-0.003	
1-5		54.15	60	114.15	95	-0.007	
1-8		32.49	60	92.49	105	-0.001	
1-11		10.83	60	70.83	170	0.037	
1-3		75.81	60	135.81	85	-0.004	
1-6		54.15	60	114.15	95	-0.002	
1-9		32.49	60	92.49	100	0.004	
1-12		10.83	60	70.83	140	0.013	
							C = 1.5
							use 0.15in diam. nozzel

VELOCITY TRAVERSE DATA SHEET

Plant Pit Incinerator

Date 5-7-70

Test Number 1-2

Sampling Location Section No. 2

Wet Bulb Temperature, °F, T_{bj}

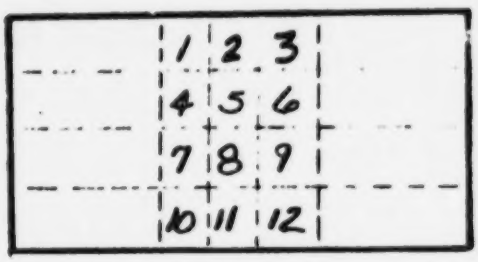
Dry Bulb Temperature, °F, T_{bk}

Stack Gage Pressure, "H_2O

Stack Diameter

Operators

Drawing of Stock



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Point No.	% of Diam.	Distance from inside Wall to Sampling Point (in)	Add Factor (in.)	Distance from Reference Point (in.)	Stack Temp., (°F)	Velocity Head or ΔP, ("H_2O) V	Comments
2-10	N.A.	10.83	60	70.83	155	0.080	
2-7		32.49	60	92.49	130	-0.007	
2-4		54.15	60	114.15	95	-0.006	
2-1		75.81	60	135.81	75	-0.009	
2-11		10.83	60	70.83	115	0.210	
2-8		32.49	60	12.49	110	0.034	
2-5		54.15	60	114.15	70	0.002	
2-2		75.81	60	135.81	90	-0.007	
2-12		10.83	60	70.83	170	0.045	
2-9		32.49	60	92.49	155	0.012	
2-6		54.15	60	114.15	130	0.004	
2-3		75.81	60	135.81	125	-0.003	

C = 1.5
used 0.375 in diam. nozzel

Plant Pit Incinerator

Date 5-7-70

Test Number 1-3

Sampling location Section No. 3

Wet Bulb Temperature, °F, T_{wb}

Dry Bulb Temperature, °F, T_{db}

Stack Gage Pressure, $"H_2O$

Stack Diameter

Operators

Drawing of Stack

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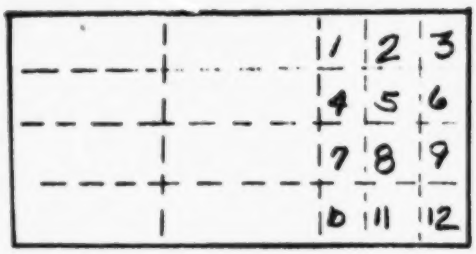

Point No.	% of Diam.	Distance from Inside Wall to Sampling Point (in.)	Add Factor (in.)	Distance from Reference Point (in.)	Stack Temp., (°F)	Velocity Head or ΔP, ($"H_2O$) V	Comments
3-10	N.A.	10.83	60	70.63	200	0.003	
3-7		32.49	60	92.49	170	-0.002	
3-4		54.15	60	114.15	150	-0.005	
3-1		75.81	60	135.81	110	-0.005	
3-11		10.83	60	70.83	95	-0.003	
3-8		32.49	60	92.49	100	-0.006	
3-5		54.15	60	114.15	93	-0.005	
3-2		75.81	60	135.81	93	-0.006	
3-12		10.83	60	70.83	110	0.005	
3-9		32.49	60	92.49	125	0.000	
3-6		54.15	60	114.15	115	-0.003	
3-3		75.81	60	135.81	130	-0.003	

C = 1.3
use 0.749 in diam nozzel

Particulate Sampling Train Data

Plant: Pit Incinerator
Test No.: 1-1
Sampling Point Location: Section No. 1
Test Conditions: Clear, warm, 73°
Barometric Pressure, "Hg, Paa:

Assumed meter temp., °F, Tm	120
Assumed moisture %	2.0
Assumed meter press., "Hg, Pm	29.7
Stack abs. press., "Hg, Ps	29.7
Correction Factor "C"	1.5
Probe heater setting	
Probe length, ft.	12
Collection box setting, °F	250
Nozzle diameter, in., Dav	0.501

Date: 5-7-70
Control Box No.: 1
Collection Box No.: 1
Time: Start 1:00pm Finish 6:24pm
Interval, min.: 5 min
Operator: RP
Assistant:

Time (min) T_{aw}	Point No.	DRY GAS METER: Reading (cu.ft.) V_{ac}	DRY GAS METER: Inlet Temp. (°F) T_{ad}	DRY GAS METER: Outlet Temp. (°F) T_{ae}	Orifice ΔH ("H_2O) P_{af}	Pitot ΔP ("H_2O) V	Stack Temp. (°F) T_{df}	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	—	32.68	—	—	0.13	-0.025	130	—	—	230	0.020	Initial Readings
	12	33.62	81	85	0.13	-0.030	130	0.0	84	230	0.020	
	5	34.48	83	86	0.10	0.004	180	0.0	85	235	0.021	
	5	36.08	89	88	0.34	0.003	110	0.8	74	235	0.018	
	2	38.74	96	91	1.20	0.011	80	2.1	65	240	0.018	
	11	39.67	100	95	0.11	-0.030	110	0.2	77	230	0.018	
	7	41.94	107	97	0.80	0.009	130	1.8	70	250	0.020	
	2	42.81	109	100	0.08	-0.010	110	0.2	78	240	0.018	
	12	43.50	117	104	0.07	-0.030	90	0.1	83	250	0.018	
	7	45.59	112	105	0.73	0.008	200	1.8	74	255	0.022	
	10	46.24	112	108	0.06	-0.025	170	0.1	82	225	0.021	
	1	48.15	113	109	0.54	0.005	210	1.7	73	230	0.022	
	4	49.65	116	110	0.31	0.003	130	0.9	75	245	0.020	
	6	51.76	120	111	0.62	0.007	110	1.7	73	245	0.018	
	1	53.52	124	113	0.45	0.005	100	1.0	74	245	0.018	
	4	55.74	127	115	0.86	0.009	130	1.8	75	255	0.020	
	11	56.55	124	116	0.06	-0.010	110	0.2	81	245	0.018	

Particulate Sampling Train Data

Plant _____

Test No. 1-1 Con't.

Sampling Point Location _____

_____

_____

Test Conditions _____

_____

Barometric Pressure, "Hg, P_{aa} _____

Assumed meter temp., °F, T_m ____
Assumed moisture % _____
Assumed meter press., "Hg, Pm ____
Stack abs. press., "Hg, Ps ____
Correction Factor "C" _____
Probe heater setting _____
Probe length, ft. _____
Collection box setting, °F ____
Nozzle diameter, in., D_{av} ____

Date _____

Control Box No. _____

Collection Box No. _____

Time
Start _____ Finish _____
Interval, min. _____

Operator _____

Assistant _____

Time (min) T_{aw}	Point No.	DRY GAS METER Reading (cu.ft.) V_{ac}	DRY GAS METER Inlet Temp. (°F) T_{ad}	DRY GAS METER Outlet Temp. (°F) T_{ae}	Orifice ΔH ("H_2O) P_{af}	Pitot ΔP ("H_2O) V	Stack Temp. (°F) T_{df}	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	___		___	___				___	___			Initial Readings
	6	58.83	126	116	0.70	0.007	130	1.4	74	240	0.20	
	9	60.35	127	118	0.31	0.003	140	0.7	74	230	0.21	
	8	62.11	127	118	0.42	0.004	120	0.8	74	235	0.19	
	8	63.64	130	119	0.16	0.001	140	0.2	74	250	0.21	
	3	65.27	129	119	0.36	0.003	100	1.0	73	235	0.018	
	9	66.05	128	120	0.04	-0.020	130	0.0	78	250	0.020	
	3	66.71	124	121	0.04	-0.018	200	0.0	82	250	0.022	
	10	67.13	124	122	0.03	-0.035	110	0.0	82	235	0.018	

Particulate Sampling Train Data

Plant: Pit Incinerator
Test No.: 1-2
Sampling Point Location: Section No. 2
Test Conditions:
Barometric Pressure, "Hg, Paa:

Assumed meter temp., °F, Tm: 120
Assumed moisture %: 2.0
Assumed meter press., "Hg, Pm: 29.9
Stack abs. press., "Hg, Ps: 29.9
Correction Factor "C": 1.5
Probe heater setting:
Probe length, ft.: 12.0
Collection box setting, °F: 250
Nozzle diameter, in., Dav: 0.375

Date: 5-7-70
Control Box No.: 2
Collection Box No.: 2
Time: Start 4:00pm Finish 6:24pm
Interval, min.: 5
Operator: WA
Assistant:

Time (min) T_{aw}	Point No.	DRY GAS METER: Reading (cu.ft. V_{ac})	DRY GAS METER: Inlet Temp. (°F) T_{ad}	DRY GAS METER: Outlet Temp. (°F) T_{ae}	Orifice ΔH ("H_2O) P_{af}	Pitot ΔP ("H_2O) V	Stack Temp. (°F) T_{df}	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	—	35.45	—	—	0.21	0.007		—	—			Initial Readings
	8	36.78	87	87	0.24	0.0075	150		82	232		
	12	—	90	87	1.95	0.075	190		77	240		
	1	42.22	95	90	0.62	0.022	150		74	240		
	10	44.95	100	92	1.25	0.044	100		73	235		
	11	47.42	104	95	1.20	0.042	150		73	240		
	6	48.33	104	98	0.12	0.005	200		79	240		
	7	49.64	106	100	0.24	0.008	230		78	240		
	9	50.98	108	104	0.27	0.010	295		82	245		
	11	53.21	114	107	0.80	0.035	375		77	260		
	8	54.08	112	108	0.09	0.004	260		81	230		
	10	56.33	116	110	0.68	0.030	310		85	235		
	6	57.12	114	111	0.07	0.002	225		81	260		
	2	58.08	117	113	0.11	0.004	170		83	260		
	9	57.03	119	115	0.13	0.004	170		79	260		
	2	59.67	118	115	0.0	-0.001	100		81	260		
	3	60.29	118	115	0.0	-0.007	170		83	260		

Particulate Sampling Train Data

Plant _____

Test No. 1-2 Con't.

Sampling Point Location _____

_____

_____

Test Conditions _____

_____

Barometric Pressure, "Hg, Paa _____

Assumed meter temp., °F, Tm ____
Assumed moisture % _____
Assumed meter press., "Hg, Pm ____
Stack abs. press., "Hg, Ps ____
Correction Factor "C" _____
Probe heater setting _____
Probe length, ft. _____
Collection box setting, °F ____
Nozzle diameter, in., Dav ____

Date _____

Control Box No. _____

Collection Box No. _____

Time
Start _____ Finish _____
Interval, min. _____

Operator _____

Assistant _____

Time (min) T_{aw}	Point No.	DRY GAS METER: Reading (cu.ft.) V_{ac}	DRY GAS METER: Inlet Temp. (°F) T_{ad}	DRY GAS METER: Outlet Temp. (°F) T_{ae}	Orifice ΔH ("H_2O) P_{af}	Pitot ΔP ("H_2O) V	Stack Temp. (°F) T_{df}	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	___		___	___				___	_____			Initial Readings
	4	60.95	118	116	0.10	0.003	170	0	83	250		
	3	61.47	119	118	0.00	-0.005	150	0	83	245		
	5	62.11	119	118	0.10	0.003	150	0	83	260		
	7	62.89	120	119	0.10	0.003	275	0	82	260		
	4	63.63	120	119	0.09	0.002	240	0	82	265		
	12	66.41	125	121	1.50	0.060	340	0	79	240		
	5	66.92	123	120	0.10	0.001	425	0	78	240		
	1	67.80	122	120	0.11	0.004	215	0	78	255		

Particulate Sampling Train Data

Plant: Pit incinerator
Test No.: 1-3
Sampling Point Location: Section No. 3
Test Conditions:
Barometric Pressure, "Hg, Paa:

Assumed meter temp., °F, Tm: 120
Assumed moisture %: 2.0
Assumed meter press., "Hg, Pm: 29.9
Stack abs. press., "Hg, Ps: 29.9
Correction Factor "C": 1.3
Probe heater setting:
Probe length, ft.: 12.0
Collection box setting, °F: 250
Nozzle diameter, in., Dav: 0.249

Date: 5-7-70
Control Box No.: 3
Collection Box No.: 3
Time: Start 4:00 pm Finish 6:24 pm
Interval, min.: 5
Operator: JH
Assistant:

Time (min) Taw	Point No.	DRY GAS METER: Reading (cu.ft.) Vac	DRY GAS METER: Inlet Temp. (°F) Tad	DRY GAS METER: Outlet Temp. (°F) Tae	Orifice ΔH ("H2O) Paf	Pitot ΔP ("H2O) V	Stack Temp. (°F) Tdf	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	—	43.19	—	—	0.0	-0.001	130	—	—		0.005	Initial Readings
	1	44.53	86	91	0.50	0.001	110	0	80	250	.005	-0.001 to 0.002
	6	46.80	93	92	2.00	0.005	90	5	89	255	.0048	-0.002 to 0.008
	3	48.58	98	95	0.0	0.0	80	0	87	240	.0046	-0.004 to 0.008
	9	50.83	97	95	1.10	0.0025	80	1	87	245	.0044	-0.003 to 0.006
	10	56.76	112	100	5.5	0.05	110	17	70	250	.0044	0.055 to 0.70
	3	59.17	114	112	0.80	0.002	210	15	81	240	.0050	-0.020 to 0.040
	6	62.08	118	115	1.35	0.004	120	3	77	245	.0056	0.02 to 0.060
	5	62.90	113	106	0.0	0.0	120	0	83	230	.0048	0.0 to 0.02
	9	63.58	112	108	0.30	0.005	100	0	82	225	.0048	-0.02 to 0.01
	10	66.25	112	109	3.8	0.010	140	0	76	260	.0047	
	4	66.32	110	110	0.0	0.0	100	0	80	230	.0052	
	8	66.66	108	109	0.0	0.0	130	0	83	255	.0047	
	4	67.48	113	111	0.25	0.005	130	0	81	235	.0050	
	5	69.73	120	114	4.0	0.011	100	7	73	240	.0050	
	1	71.85	118	114	1.30	0.003	100	4	74	235	.0047	
	7	75.50	123	114	2.0	0.005	150	0	75	250	.0047	

Particulate Sampling Train Data

Plant _____

Test No. 1-3 Con't.

Sampling Point Location _____

_____

_____

Test Conditions _____

_____

Barometric Pressure, "Hg, P_{aa} _____

Assumed meter temp., °F, T_m ____
Assumed moisture % _____
Assumed meter press., "Hg, Pm ____
Stack abs. press., "Hg, Ps ____
Correction Factor "C" _____
Probe heater setting _____
Probe length, ft. _____
Collection box setting, °F ____
Nozzle diameter, in., Dav ____

Date _____

Control Box No. _____

Collection Box No. _____

Time
Start _____ Finish _____
Interval, min. _____

Operator _____

Assistant _____

Time (min) T_{aw}	Point No.	DRY GAS METER Reading (cu.ft.) V_{ac}	DRY GAS METER Inlet Temp. (°F) T_{ad}	DRY GAS METER Outlet Temp. (°F) T_{ae}	Orifice ΔH ("H_2O) P_{af}	Pitot ΔP ("H_2O) V	Stack Temp. (°F) T_{df}	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	___		___	___				___	___			Initial Readings
	2	78.86	130	116	3.5	0.01	200	5	75	250		
	11	85.93	134	117	7.0	0.025	150	13	75	245		
	2	90.02	134	117	1.7	0.025	220	1	77	255		
	12	96.82	144	118	7.0	0.025	200	13	75	255		
	7	102.74	140	118	4.5	0.015	180	7	75	260		
	11	108.47	138	117	7.0	0.025	180	15	77	250		
	8	112.88	134	117	3.5	0.010	160	6	78	260		
	12	119.80	140	118	6.0	0.020	450	14	88	270		

Particulate Sampling Train Data

Plant: Pt Incinerator
Test No.: 2-1
Sampling Point Location: Section No. 1
Test Conditions: Clear, Warm, 80°
Barometric Pressure, "Hg, P_{aa}:

Assumed meter temp., °F, T_m: 110
Assumed moisture %: 2.0
Assumed meter press., "Hg, Pm:
Stack abs. press., "Hg, Ps:
Correction Factor "C": 1.5
Probe heater setting:
Probe length, ft.:
Collection box setting, °F:
Nozzle diameter, in., Dav: 0.501

Date: 5-8-70
Control Box No.: 2
Collection Box No.: 5
Time
Start: 1:00 pm Finish: 2:30 pm
Interval, min.: 4
Operator: RP
Assistant:

Time (min) T_{aw}	Point No.	DRY GAS METER Reading (cu.ft.) V_{ac}	DRY GAS METER Inlet Temp. (°F) T_{ad}	DRY GAS METER Outlet Temp. (°F) T_{ae}	Orifice ΔH ("H_2O) P_{af}	Pitot ΔP ("H_2O) V	Stack Temp. (°F) T_{df}	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	—	67.13	—	—	0.23	0.002	120	—	—		0.19	Initial Readings
	2	68.19	93	95	0.12	0.001	120	0.0	78	230	0.19	
	5	68.95	94	95	0.11	0.001	220	0.0	82	245	0.23	
	11	70.10	96	95	0.22	0.004	350	0.5	80	225	0.27	
	8	71.33	99	96	0.29	0.003	200	0.5	75	245	0.22	
	4	72.03	99	97	0.07	0.00	240	0.0	85	245	0.23	
	10	72.67	100	98	0.06	-0.001	240	0.0	85	235	0.23	
	1	73.23	103	100	0.07	-0.001	260	0.0	85	225	0.24	
	7	73.79	105	101	0.04	-0.002	220	0.0	88	250	0.23	
	9	74.20	98	99	0.05	-0.010	380	0.0	94	250	0.28	
	12	74.71	100	100	0.05	0.0	430	0.0	92	245	0.30	
	6	75.12	101	101	0.05	-0.003	420	0.0	93	250	0.40	
	3	75.64	104	103	0.09	-0.002	460	0.0	93	250	0.30	

Particulate Sampling Train Data

Plant: rt Incinerator
Test No.: 2-2
Sampling Point Location: Section No. 2
Test Conditions:
Barometric Pressure, "Hg, Paa:

Assumed meter temp., °F, Tm: 110
Assumed moisture %: 2.0
Assumed meter press., "Hg, Pm:
Stack abs. press., "Hg, Ps:
Correction Factor "C": 1.5
Probe heater setting:
Probe length, ft.:
Collection box setting, °F:
Nozzle diameter, in., Dav: 0.501

Date: 5-8-70
Control Box No.: 2
Collection Box No.: 5
Time
Start: 12:56pm Finish: 2:30pm
Interval, min.: 4
Operator: WA
Assistant:

Time (min) T_{aw}	Point No.	DRY GAS METER Reading (cu.ft.) V_{ac}	DRY GAS METER Inlet Temp. (°F) T_{ad}	DRY GAS METER Outlet Temp. (°F) T_{ae}	Orifice ΔH ("H_2O) P_{af}	Pitot ΔP ("H_2O) V	Stack Temp. (°F) T_{df}	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	—	67.80	—	—	0.15	0.002		—	—		0.028	Initial Readings
	1	68.31	78	80	0.0	0.0	375	0.5	88	180	0.029	
	7	69.05	80	80	0.15	0.002	470	4.0	86	185	0037	
	10	69.78	81	81	0.10	0.001	600+	3.0	84	200	0.036	50-600° Dial thermometer
	4	70.42	82	82	0.12	0.002	600+	2.0	85	200	0.036	
	12	70.83	85	85	0.10	0.001	365	0.5	86	205	0.030	
	9	71.46	89	85	0.10	0.001	600+	25.0	86	245	0.044	changed filter; started
	3	76.78	96	89	1.70	0.035	600+	3.0	85	240	0.04	to sample point twice,
	6	77.79	100	90	0.16	0.003	600+	3.0	80	100	0.048	add 1.5 minutes to
	2	—	100	92	1.90	0.050	600+	3.0	75	100	0.048	length of test
	8	81.39	104	93	0.22	0.005	600+	2.0	78	100	0.044	
	11	82.07	102	95	0.13	0.003	600+	2.0	80	100	0.038	
	5	82.77	105	97	0.0	0.002	600+	2.0	80	100	—	terminate test due
												to lack of waste

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Particulate Sampling Train Data

Plant P.I Incinerator

Test No. 2-3

Sampling Point Location Section No. 3

Test Conditions

Barometric Pressure, "Hg. Pba

Assumed meter temp., °F, Tm 110
Assumed moisture % 2.0
Assumed meter press., "Hg. Pm
Stack abs. press., "Hg. Ps
Correction Factor "C" 1.3
Probe heater setting
Probe length, ft.
Collection box setting, °F
Nozzle diameter, in., Dav 0.501

Date 5-8-70

Control Box No. 3

Collection Box No. 6

Time
Start Finish
Interval, min. 4

Operator JH

Assistant

Time (min) Tav	Point No.	DRY GAS METER Reading (cu. ft.) Vac	Inlet Temp. (°F) Tad	Outlet Temp. (°F) Tae	Orifice ΔH ("H2O) ΔHav	Pitot ΔP ("H2O)	Stack Temp. (°F) Ts	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Rot. Δ	Comments
Zero	—	119.80	—	—			300	—	—		0.030	Initial Readings
	1	119.74	87	87	0.00	0.00	480	0	88	260	0.038	
	7	120.38	88	88	0.13	0.002	570	0	85	230	0.042	
	4	121.30	88	88	0.55	0.01	480	0	87	225	0.038	
	10	121.74	92	89	0.12	0.0015	240	0	81	210	0.029	lost of electrical power
	5	122.80	97	92	0.37	0.005	560	0	88	245	0.042	
	8	123.21	97	94	0.10	0.0015	450	0	82	245	0.037	
	11	124.95	100	96	0.84	0.015	190	5	76	245	0.026	
	2	125.46	104	99	0.00	0.0	520	0	78	235	0.040	
	3	126.00	100	100	0.05	0.001	400	0	78	225	0.035	
	12	127.15	103	101	0.30	0.005	370	0	78	245	0.034	
	6	128.15	107	103	0.28	0.004	470	0	78	245	0.038	
	9	129.31	112	104	0.40	0.007	290	1	75	250	0.030	

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Particulate Sampling Train Data

Plant: R.T Incinerator

Test No.: 3-1

Sampling Point Location: Section No. 1

Test Conditions: Clear, Warm, 80°

Barometric Pressure, "Hg, Pba

Assumed meter temp., °F, Tm: 110
Assumed moisture %: 20
Assumed meter press., "Hg, Pm
Stack abs. press., "Hg, Ps
Correction Factor "C": 1.5
Probe heater setting
Probe length, ft.
Collection box setting, °F
Nozzle diameter, in., Dav: 0.501

Date: 5-8-70

Control Box No.: 1

Collection Box No.: 1

Time
Start: 3:55pm Finish
Interval, min.: 4

Operator: RP

Assistant

Time (min) Cum	Point No.	GAS METER Reading (cu.ft.) Vac	GAS METER Inlet Temp. (°F) Tad	GAS METER Outlet Temp. (°F) Tde	Orifice ΔH ("H2O) Pdf	Pilot ΔP ("H2O) V	Stack Temp. (°F) Ts	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	—	75.64	—	—	0.0	0.002	160	—	—	260	0.21	Initial Readings
2	2	76.21	96	99	0.10	-0.003	160	0.0	90	240	0.21	
5	5	76.87	96	97	0.10	0.001	370	0.0	91	245	0.28	
11	11	77.45	99	99	0.10	-0.002	370	0.0	93	245	0.28	
8	8	78.02	102	101	0.09	-0.005	480	0.0	98	260	0.32	
4	4	78.51	102	104	0.09	-0.003	350	0.0	89	265	0.27	
10	10	79.12	107	105	0.63	0.020	470	0.0	81	260	0.32	
1	1	80.93	115	106	0.23	-0.002	610	0.0	86	265	0.37	
7	7	81.45	115	108	0.10	-0.003	530	0.0	89	235	0.34	
9	9	82.11	115	109	0.15	-0.006	440	0.0	91	245	0.31	
12	12	82.91	117	110	0.14	0.002	500	0.0	86	240	0.33	
6	6	83.70	122	112	0.16	0.002	410	0.0	93	260	0.30	
3	3	84.00	130	115	0.06	-0.011	480	0.0	92	260	0.32	
2	2	84.45	120	111	0.10	-0.005	340	0.0	92	265	0.27	
5	5	84.75	120	113	0.07	-0.005	420	0.0	81	250	0.30	
11	11	85.13	126	118	0.53	0.008	410	1.0	86	240	0.30	
8	8	86.68	129	119	0.13	-0.003	740	0.0	87	235	0.40	

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Particulate Sampling Train Data

Plant _____

Test No. 3-1 Con't.

Sampling Point Location _____

Test Conditions _____

Barometric Pressure, "Hg, Pba

Assumed meter temp., °F, Tm ____
Assumed moisture % _____
Assumed meter press., "Hg, Pm ____
Stack abs. press., "Hg, Ps ____
Correction Factor "C" _____
Probe heater setting _____
Probe length, ft. _____
Collection box setting, °F ____
Nozzle diameter, in., Dav ____

Date _____

Control Box No. _____

Collection Box No. _____

Time
Start _____ Finish _____
Interval, min. _____

Operator _____

Assistant _____

Time (min) Tav	Point No.	DRY GAS METER Reading (cu.ft.) Vac	DRY GAS METER Inlet Temp. (°F) Tad	DRY GAS METER Outlet Temp. (°F) Tao	Orifice ΔH ("H2O) Par	Pitot ΔP ("H2O) V	Stack Temp. (°F) Tds	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero												Initial Readings
	4	87.26	127	120	0.14	-0.002	540	0.0	75	260	0.36	
	10	88.92	136	122	0.80	0.018	600	1.3	77	235	0.37	
	1	89.55	136	123	0.10	-0.004	330	0.0	90	245	0.26	
	7	89.89	132	125+	0.09	-0.004	250	0.0	93	260	0.25	Tao off scale
	9	90.60	130	125+	0.10	0.001	340	0.0	78	250	0.27	Tao off scale
	12	95.10	149	125+	1.35	0.030	800	13.0	82	255	0.44	Tao off scale
	6	95.82	151	125+	0.15	-0.003	620	0.9	11	235	0.37	Tao off scale
	3	96.51	144	125+	0.10	-0.006	380	0.0	90	240	0.28	Tao off scale

Particulate Sampling Train Data

Plant: T, T Incinerator
Test No.: 3-2
Sampling Point Location: Section No. 2
Test Conditions:

Assumed meter temp., °F, Tm: 110
Assumed moisture: 20
Assumed meter press., "Hg, Pm:
Stack abs. press., "Hg, Ps:
Correction Factor "C": 1.5
Probe heater setting:
Probe length, ft.:
Collection box setting:
Nozzle diameter, in., Dn: 0.501

Date: 5-8-70
Control Box No.: 2
Collection Box No.:
Time: Start 5:50pm Finish:
Interval, min.:
Operator: WA
Assistant:

Barometric Pressure, "Hg, Pbar:

Time (min)	Point No.	Dry gas meter reading (cu. ft.)	Dry gas meter temp. (°F) Inlet Tdi	Dry gas meter temp. (°F) Outlet Tdo	Orifice ΔH (in. H2O)	Orifice Δp (in. H2O)	Stack Temp. (°F) Ts	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Rotameter Reading ΔP	Comments
Zero		82.77			1.45	0.005					0.022	Initial Readings
1		83.34	92	95	0.0	0.0	515	0	89	250	0.034	
7		84.53	15	17	1.40	1.007	625	0	87	240	0.038	
10		24.13	18	98	1.0	0.015	870	0	83	220	0.046	
4		15.165	102	100	0.18	0.004	750	0	88	220	0.048	
2		4.06	100	101	1.0	-0.005	1100*	0	74	260		*estimated T/C because maximum reading on dial thermometer is 1,000°F
8		8732	104	103	0.55	2.010	730	2	79	265		
11		87.92	110	105	1.0	0.0	750	1	65	235		
5		88.73	110	106	0.18	0.003	875	0	82	240		
12		89.52	10	108	0.24	0.004	1000	3	86	260		
9		90.56	112	109	0.24	0.004	775	1	78	260		
3		91.52	116	111	0.21	0.005	810	0	86	240		
6		92.58	117	112	0.21	0.006	850	0	53	260		
1		93.57	117	113	0.22	0.005	760	0	84	235		
7		9443	118	114	0.22	0.005	830	0	88	240		
10		95.16	115	115	0.10	0.002	125	0	85	260		
4		16.11	119	115	0.26	0.006	125	0	81	235		

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Particulate Sampling Train Data

Plant _____

Test No. 3-2 Con.t.

Sampling Point Location _____

Test Conditions _____

Barometric Pressure, "Hg, Pbar _____

Assumed meter temp., °F, Tm _____
Assumed moisture % _____
Assumed meter press., "Hg, Pm _____
Stack abs. press., "Hg, Ps _____
Correction Factor "C" _____
Probe heater setting _____
Probe length, ft. _____
Collection box setting, °F _____
Nozzle diameter, in., Dav _____

Date _____

Control Box No. _____

Collection Box No. _____

Time
Start _____ Finish _____
Interval, min. _____

Operator _____

Assistant _____

Time (min) Tav	Point No.	Dry Gas Meter Reading (cu.ft.) Vac	Dry Gas Meter Inlet Temp. (°F) Tad	Dry Gas Meter Outlet Temp. (°F) Tae	Orifice ΔH ("H2O) Dar	Pilot ΔP ("H2O) V	Stack Temp. (°F) Tdf	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	—		—	—				—	—			Initial Readings
	2	96.93	119	116	0.22	0.005	775	0	86	265		2
	8	97.94	123	118	0.13	0.003	710	0	82	235		1
	11	98.69	122	119	0.13	0.003	1000	0	86	250		
	5	99.82	125	120	0.22	0.005	840	0	84	260		
	12	100.55	120	118	0.0	-0.002	860	0	88	260		
	9	101.55	120	119	0.31	0.007	920	0	92	235		
	3	102.35	119	119	0.45	0.010	800	0	92	235		
	6	103.62	124	120	0.0	0.0	730	1	82	240		

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Plant Pit Incinerator

Test No. 3-3

Sampling Point Location Stack No 3

Test Conditions

Particulate Sampling Train Data

Assumed meter temp., °F, Tm 110
Assumed moisture % 2.0
Assumed meter press., "Hg, Pm
Stack abs. press., "Hg, Ps
Correction Factor "C" 1.3
Probe heater setting
Probe length, ft.
Collection box setting, °F
Nozzle diameter, in., Dav .501

Date 5-8-70

Control Box No. 3

Collection Box No.

Time
Start 3:50 pm Finish
Interval, min. 4

Operator JH

Assistant

Barometric Pressure, "Hg, Pbar

Time (min)	Point No.	Dry Gas Meter Reading (cu. ft.) Vac	Dry Gas Meter Temp. (°F) Inlet Tad	Dry Gas Meter Temp. (°F) Outlet Tdo	Orifice ΔH ("H2O) Pdf	Pitot ΔP ("H2O)	Stack Temp. (°F) Tds	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
							380	—	—		0.034	Initial Readings
Zero	—	129.31	—	—								
—	1	130.10	100	104	0.13	0.002	660	0	88	240	0.045	
—	7	131.19	102	104	0.25	0.005	420	0	82	230	0.036	
—	4	132.57	107	105	0.42	0.007	520	1	77	245	0.040	
—	10	133.10	108	105	0.12	0.002	700	0	84	225	0.048	
—	5	134.36	110	106	0.40	0.007	480	0	96	240	0.038	
—	8	135.12	111	109	0.20	0.004	660	0	89	225	0.044	
—	11	135.64	115	110	0.10	0.0018	1050	0	70	245	0.060	
—	2	136.61	114	111	0.10	0.0025	170	0	73	235	0.025	
—	3	136.80	115	112	0.0	0.0	420	0	72	240	0.036	
—	12	137.03	114	114	0.0	0.0	290	0	73	240	0.031	
—	6	137.73	120	116	0.15	0.002	510	0	87	230	0.040	
—	9	138.52	120	117	0.10	0.0015	350	0	71	235	0.033	
—	1	139.31	122	118	0.10	0.004	350	0	86	225	0.033	
—	7	140.04	124	118	0.14	0.002	620	0	85	230	0.041	
—	4	140.94	128	120	0.33	0.003	290	0	84	230	0.031	
—	10	141.61	128	121	0.30	0.004	350	0	87	250	0.033	

Particulate Sampling Train Data

Plant _____

Test No. 3-3 Con't.

Sampling Point Location _____

Test Conditions _____

Barometric Pressure, "Hg, Pbar _____

Assumed meter temp., °F, Tm ____
Assumed moisture % ____
Assumed meter press., "Hg, Pm ____
Stack abs. press., "Hg, Ps ____
Correction Factor "C" ____
Probe heater setting ____
Probe length, ft. ____
Collection box setting, °F ____
Nozzle diameter, in., Dav ____

Date _____

Control Box No. _____

Collection Box No. _____

Time
Start _____ Finish _____
Interval, min. _____

Operator _____

Assistant _____

Time (min) Θ	Point No.	DRY GAS METER Reading (cu.ft.) Vac	Inlet Temp. (°F) Tad	Outlet Temp. (°F) Tas	Orifice ΔH ("H2O) Paf	Jet ΔP ("H2O) V	Stack Temp. (°F) Tdf	Pump Vacuum ("Hg)	Impinger Outlet Temp. (°F)	Collection Box Temp. (°F)	Nomograph Ref ΔP	Comments
Zero	___		___	___				___	___			
	3	142.46	125	122	0.20	0.003	490	0	86	225	0.038	Initial Readings
	9	143.21	130	123	0.15	0.002	350	0	86	220	0.033	
	11	144.25	130	124	0.24	0.003	250	0	88	225	0.030	
	2	144.84	132	125	0.15	0.002	770	0	86	240	0.059	
	3	145.43	130	125	0.11	0.003	200	0	86	240	0.029	
	12	147.25	135	126	0.70	0.010	210	2	81	250	0.027	
	6	148.45	135	127	0.29	0.003	300	2	82	230	0.031	
	9	149.88	139	128	0.40	0.006	250	2	80	250	0.030	

LABORATORY ANALYSES FOR PARTICULATE DATA*

Particulate test No.	Section No.	Water condensed in impingers (ml)	Water absorbed by silica gel (g)	Material caught by filter (mg)	Material removed by acetone wash FA+ (mg)	Material removed by acetone wash RA* (mg)	Material caught in impinger water Solvent extract (mg)	Material caught in impinger water Water residue (mg)
1	1	0	8.5	7.1	25.0	6.2	0.0	11.6
	2	0	2.1	10.8	46.0	14.0	0.4	17.1
	3	0	20.8	36.3	63.0	4.0	2.6	26.4
2	1	0	1.4	4.1	20.0	9.0	0.0	19.4
	2	0	1.0	24.2	87.0	10.2	0.0	16.1
	3	0	1.9	7.5	29.0	11.6	6.5	13.6
3	1	0	12.2	25.3	39.3	9.8	21.4	4.0
	2	0	-	34.1	103.0	9.0	25.7	2.4
	3	0	6.0	16.5	35.2	12.0	21.0	3.0

*Refer to reference number 5.

+Front acetone wash.

*Rear acetone wash.

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